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WEEKLY September 5–11, 2020

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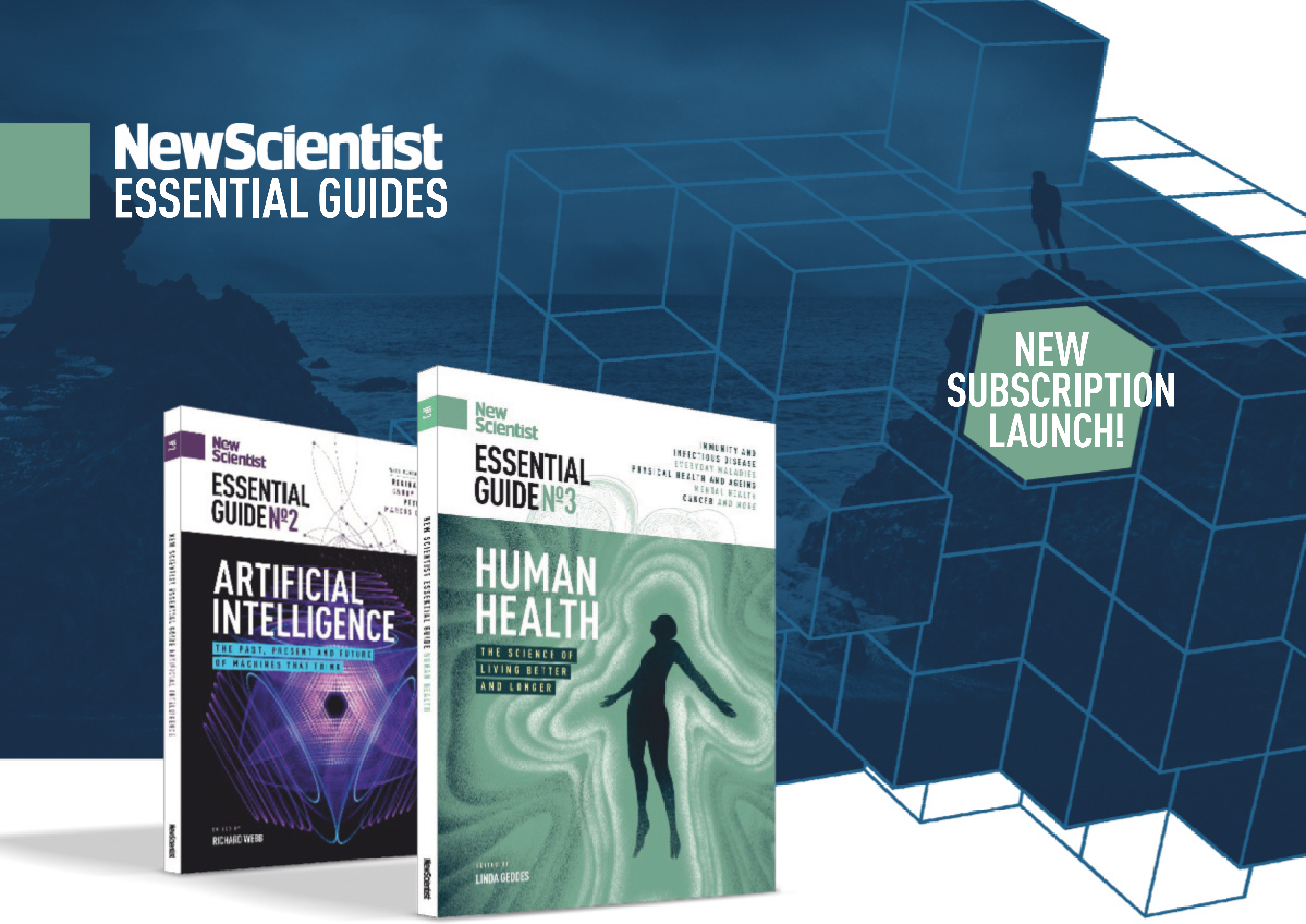
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This week's issue

On the cover

36 The flaw at the heart of reality
Why precise mathematical laws can never fully explain the universe

New Scientist
THE FLAW AT THE HEART OF REALITY

Vol 247 No 3298
Cover image: DUSK Studio

41 The moon and you
How lunar cycles really could impact your health

46 Western weirdness
Is an obsession with the West skewing psychology?

8 Back to the classroom
What we know about keeping schools safe from covid-19

16 Unlock your unconscious
14 California burning
11 Truth about T-cells
34 Star Trek boldly goes on and on

41 Features

> **"Evidence is growing that the influence of the moon is more widespread than we thought"**

News

7 Vaccine trial
Thousands of people will receive a promising coronavirus vaccine

12 Covid-19 fighter
Combating the disease in the Central African Republic

15 Universal voyager
It might be possible to pass safely through a wormhole

Views

23 Comment
Embrace tech solutions to stop drink-driving, says Amie Hayley

24 The columnist
James Wong looks into claims of toxic fruit and veg

28 Letters
How tough should we be on vaccine deniers?

30 Aperture
Colourful swirls of phytoplankton near Sweden

32 Culture
Two books reveal the reality of life for an astronaut

Insight

GARY BELL/OCEANWIDE/NATUREPL

18 Making waves The billionaires planning to geoengineer the oceans

Features

36 The flaw in reality
We expect the laws of nature that describe the universe to be exact. What if that isn't true?

41 The moon and you
It may be time to reconsider whether lunar cycles influence our health

46 Western weirdness
Psychology is failing to capture how most of the world thinks

The back pages

53 Puzzles
Cryptic crossword and the quiz

54 More puzzles
Help Septa find her PIN before she is locked out

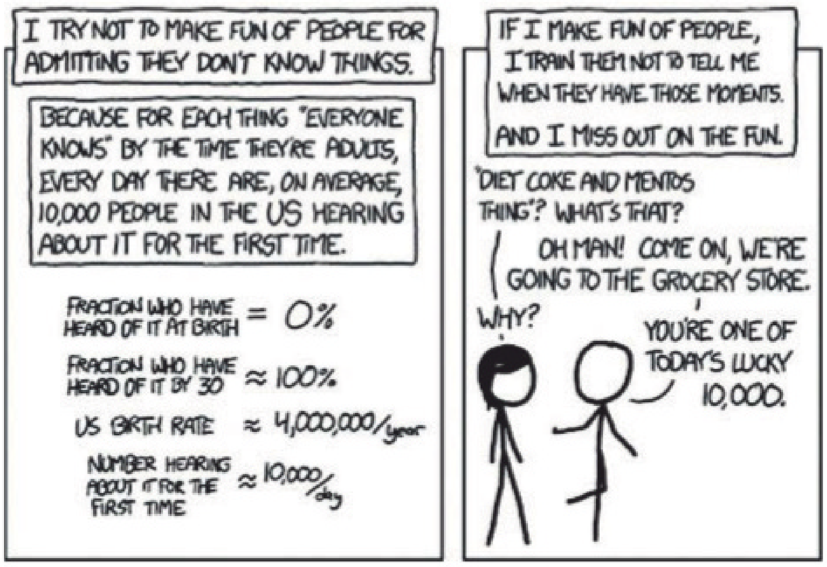
54 Cartoons
Life through the lens of Tom Gauld and Twisteddoodles

55 Feedback
Monkey business and hokey-cokey hokum: the week in weird

56 The last word
Is sleep the subconscious mind's secret weapon?

Elsewhere on New Scientist

Event


I TRY NOT TO MAKE FUN OF PEOPLE FOR ADMITTING THEY DON'T KNOW THINGS.
BECAUSE FOR EACH THING "EVERYONE KNOWS" BY THE TIME THEY'RE ADULTS, EVERY DAY THERE ARE, ON AVERAGE, 10,000 PEOPLE IN THE US HEARING ABOUT IT FOR THE FIRST TIME.
FRACTION WHO HAVE HEARD OF IT AT BIRTH = 0%
FRACTION WHO HAVE HEARD OF IT BY 30 ≈ 100%
US BIRTH RATE ≈ 4,000,000/year
NUMBER HEARING ABOUT IT FOR THE FIRST TIME ≈ 10,000/day
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WHY?
YOU'RE ONE OF TODAY'S LUCKY 10,000.

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Take my advice xkcd's Randall Munroe shares his tips for life

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Bubble trouble Sam Wong gets lost in parallel universes

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How to... with Randall Munroe

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Science with Sam

This week's video explores the wonders of the multiverse.

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A note from the editor

Although words and pictures are our bread and butter, *New Scientist* exists on many different platforms and, indeed, manifests itself very differently across them (one of those platforms being real life). It is always *New Scientist*, though – whether it is a podcast, a live event, a video, a holiday, a book or a one-off app special. In whatever we do, we strive for accuracy, as well as something I can only describe, however inadquately, as *New Scientist*-iness.

Last week, after months of planning and pandemic-interrupted production, there was a further addition to our stable of *New Scientist* iterations: Science with Sam, a weekly video series on our YouTube channel hosted by *New Scientist* social media editor Sam Wong. This year, Sam will explain some of the biggest topics in science, from microbiomes to vaccines, quantum theory to consciousness and much, much more.

> "Our new video series explains the biggest topics in science, from microbiomes to vaccines"

It is actually more than a decade since we published our first video on YouTube. Since then, we have uploaded thousands of clips showing the latest research from scientists around the world, including a baby gorilla taking its first steps, the first ever footage of human ovulation and rats driving little cars (and, as some of you will remember, the rat *steered* those tiny cars too).

More recently, we have started filming in-depth interviews with the biggest names in science, including Greta Thunberg, Richard Dawkins and James Lovelock. So far, those videos have attracted more than 200,000 subscribers, and now we are adding Science with Sam to the mix.

Our first episode was about black holes and whether or not you could escape one if you fell into it. This week, in our second episode, Sam explores the multiverse. We think it is a great primer on one of the weirdest ideas in science. Do tune in to the series every week at youtube.com/newscientist

Emily Wilson
New Scientist editor

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Widening the search for alien life on habitable planets, why unconscious bias training might not work and the microbiome of cancer tumours

Episode 30
Redefining time, why mindfulness can cause problems and secrets of super-resilient tardigrades

Episode 29
Loneliness during lockdown, medical artificial intelligence beats doctors and who gets the coronavirus vaccine first

Episode 28
Origin of life on Earth, second wave of coronavirus and the science of miscarriage

Hosted by *New Scientist*’s Rowan Hooper and Valerie Jamieson, new episodes are out each Friday. Follow us on Twitter **@newscientistpod**

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Grown-up thinking needed

Politicians must be flexible to help schools stay open

THE start of a new school year is always a significant moment for children, but never more so than this year. When schools in England, the US and many other nations reopen their doors this September, it will be the first time in months that the majority of children have stepped foot in a classroom.

These children have made a big sacrifice in our fight against the coronavirus. Many teachers have made heroic efforts to suddenly switch to remote learning, but there is no doubt that pupils' education has been affected. The pandemic has also prevented progress in closing the gap in academic achievement between the most disadvantaged children in England and their peers. Those disadvantaged children are now more than 18 months behind by the time they are 16, on average.

Because of this, there is wide agreement that schools must reopen, and stay open. Achieving this is fraught with unknowns, however (see page 8). Although it seems that children are less likely to transmit and get sick from the coronavirus, we don't know why that is the case. Should an outbreak occur, pupils' families and school staff could still be at risk.

> "To keep schools safe, we must be prepared to shut down other areas of society to keep overall virus transmission low"

In order to keep schools safe, governments must be prepared to shut down other areas of society to keep overall levels of virus transmission low. If parents return to travelling, en masse, on crowded commuter lines, that will vastly increase their likelihood of catching the coronavirus and passing it to their children. If large groups begin to gather in pubs and restaurants, or choose to go to parties inside private spaces, the same applies.

This all means that managing the virus necessitates that politicians must be agile, and unafraid of U-turns. In England, a row over pupils wearing face coverings (see page 10) saw the UK government spend weeks denying it would change its policy of not requiring them, only to eventually cave in shortly before schools opened. This is a time for the grown-ups to have grown-up conversations about the difficult realities of reopening schools, so that children can get on and learn. ▮

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News

Truth about T-cells
Have we missed a trick on coronavirus immunity? p11

California wildfires
Devastating blazes probably driven by climate change p14

Video filters
AI can remove unwanted objects from video p14

Plant power
Plastic gives algae a photosynthesis upgrade p15

Quantum computing
Cosmic rays could spell disaster for exotic devices p16

A volunteer waits to take part in a covid-19 vaccine trial in Florida

CHANDAN KHANNA/AFP VIA GETTY IMAGES

Vaccine trial begins in US

Thousands of volunteers are taking part in a US trial of the Oxford vaccine, raising hopes for results this year, reports **Michael Le Page**

A LARGE trial of a coronavirus vaccine developed by the University of Oxford has begun in the US. With similar trials already under way in the UK and Brazil, hopes are rising that we could find out if the vaccine works before the end of the year.

A collaboration between the Oxford team and the drug firm AstraZeneca, this vaccine is one of the front-runners. Worldwide, eight other coronavirus vaccines have started large-scale trials, and 24 have begun smaller trials to assess safety.

On 31 August, the US National Institutes of Health announced that the first of 30,000 volunteers had received either the Oxford vaccine, known as AZD1222, or a placebo consisting of salty water. One in three volunteers will get the placebo, but the trial is double blind, meaning that neither the researchers nor the volunteers know which is being administered.

The trial is being carried out at 80 sites across the US.

In the UK, nearly 10,000 volunteers have already been given either AZD1222 or a placebo.

Once a certain number of the volunteers in these trials test positive for covid-19, researchers will be allowed to unblind the data and look to see if there are fewer – or even no – cases in those given the vaccine.

It could take some time to get to this point in the UK, as the number of daily coronavirus cases remains low post-lockdown, although the numbers are slowly increasing.

The trials in Brazil and the US might yield results sooner, as these countries have more confirmed cases per capita.

Once the results of large trials are in, regulators will consider whether to approve any vaccine.

> **"There might be enough results to put the data to regulators by the end of the year"**

The director of the Oxford vaccine group, Andrew Pollard, told the BBC last week that the team might be able to put results before regulators this year.

Last week, the UK government announced that it is considering changing the law to allow it to grant temporary approval to any vaccine from October.

Some are concerned that intense political pressure could lead to vaccines being approved prematurely, before we are certain they are safe and effective enough.

Governments have signed deals to buy hundreds of millions of doses of the various vaccines being developed if they are successful, and as trials progress, capacity for manufacturing is being ramped up.

On 1 September, for instance, biotech company Oxford Biomedica announced that it had expanded an agreement with AstraZeneca to produce 10 times as much of the Oxford vaccine as previously agreed. "We will be producing tens of millions of doses once fully up and running," says an Oxford Biomedica spokesperson. ▮

Daily coronavirus news round-up
Online every weekday at 6pm BST
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Children

How to safely reopen schools

There is no easy solution for education in the time of coronavirus, but what we have learned during the pandemic can help us open schools safely, finds **Jessica Hamzelou**

SCHOOLS across England and the US are about to reopen their doors to students who have been at home for months thanks to the coronavirus pandemic. What is the best way to keep children, and school staff and parents, safe?

Many of these schools closed towards the end of March as cases surged in both the UK and the US. Given how little we knew about the coronavirus at the time, closing schools was the right thing to do, say the researchers contacted by *New Scientist*.

But we have learned a lot about how the virus spreads and who is at the greatest risk since then. While many questions remain, keeping children out of school is likely to be more harmful to them, and to society, in the long run.

Back in March, many decisions about the coronavirus were based on what was known about other respiratory viruses, like the flu. “Kids are the main sustainers of transmission of influenza,” says Benjamin Linas at Boston University. “But covid-19 is not influenza.”

Unlike with flu, children seem far less likely than adults to have symptomatic or severe cases of covid-19. In February, a report covering 72,314 cases of the disease in China found that only 1 per cent were in children under the age of 10 (*JAMA*, doi.org/ggmq43). Similar trends have been seen in other countries since, including the US.

Children aren’t immune, and some do appear to develop a multi-system inflammatory syndrome, which can be fatal, but this seems to be extremely rare. In one recent study, Olivia Swann at the University of Edinburgh, UK, and her colleagues followed the outcomes of 627 young people under the age of 19 who had been admitted to UK hospitals with confirmed cases of covid-19. Six of the children died, all of whom had other conditions (*BMJ*, doi.org/d7pc). Half of the deaths were in very premature babies with heart problems and sepsis, for example.

It isn’t clear why children seem to be less likely to get very sick with covid-19. “The theory – and it’s just a theory – is that, because children have had less exposure to coronaviruses, their immune systems may be less activated [by the coronavirus],” says Dimitri Christakis at Seattle Children’s Research Institute. Overreactions of adult immune systems – known as cytokine storms – are thought to be a common complication in severe covid-19 cases, and severe reactions are rare in children.

“If we knew in March what we know now, I would say we shouldn’t have closed primary schools”

Children seem to be less likely to transmit the virus than adults, according to the data we have so far. While schools closed for most young people in England in March, they remained open for the children of key workers and those with special educational needs. In June, schools reopened for children aged 5 to 6, 10 to 11, and for older teens and those attending nursery. By the end of June, 1.6 million children were attending educational settings.

Only 70 of these children have tested positive for the virus, according to a report by Public Health England (PHE). These cases tended to occur in areas experiencing high levels of the virus in the community, say the authors of the report.

There are also concerns that school staff members and children’s families might be put at risk when schools reopen.

LAUREN DECICCA/GETTY IMAGES

The PHE report identified 198 confirmed cases in school staff, one of whom was hospitalised. Over the period, one teacher died following an infection, but this person caught the virus from a household member, rather than in school, the report states.

Adult transmission

Evidence suggests that adults might be more likely to spread the virus than children, particularly younger children. A large study from South Korea, which traced the 59,073 contacts of 5706 people with covid-19, found that children younger than 10 were the least likely to transmit the virus to others.

While such findings are far from conclusive – asymptomatic cases could still be missed, for example – it appears that adults are more likely to be spreading the virus in schools than young children. In England, seven outbreaks in which two or more people were infected occurred in early-years settings in June, and all were triggered by an adult staff member, according to the PHE report.

No one knows why young children might be less likely to spread the coronavirus, but there are many hypotheses. It might be because children are less likely to have severe symptoms. “Even when they’re symptomatic, they tend to expel less because they don’t sneeze or cough as vigorously,” says Christakis.

Others have suggested that height plays a role. In theory, any virus that is expelled by a small child is more likely than virus expelled by an adult to fall directly to the ground before coming into contact with another person.

Christakis is among a group of researchers who believe education settings for young children should have been the first to reopen. “If we knew [in March] what we know now, I would say we

Coronavirus Essential Guide
All you need to know about coronavirus and covid-19
Available now in the *New Scientist* app

Pupils returning to school wear face masks and stay distanced in Bangkok

shouldn't have closed primary schools," he says.

Before schools reopen, however, many epidemiologists believe it is key to have coronavirus cases in the community under control, and effective test, trace and isolate programmes in operation.

It takes between about eight and 10 days in the US to get a result from a coronavirus test, says Linas. Parents can't be expected to keep their children home for up to two weeks every time they get a runny nose, he says. "The fifth time that happens, are you going to do it? I'm probably not, and I'm the infectious diseases doctor," he says. "It's going to be a major problem if we don't have [rapid, accessible] testing."

153

students contracted the virus in a reopened school in Jerusalem

Without better testing, disruptions may be common. A UK government policy released on 28 August could require an entire year group in an English school to self-isolate for two weeks if two or more students test positive.

And community transmission should be kept low. There are no established criteria for how low, but low levels of transmission are generally considered to have been achieved when an area has fewer than 10 cases per 100,000 people, or when less than 5 per cent of those tested for the virus get a positive result. "There are several examples of countries that have reopened schools successfully, and I believe that nearly all the success stories are in countries that had low community prevalence when they opened," says Julie Donohue at the University of Pittsburgh in Pennsylvania.

This might go some way to explaining why reopening schools has been something of a disaster in parts of the US. Some schools in Indiana were closed days after reopening as students and staff members tested positive for the coronavirus. Given that cases in the state were rising in August, this outcome was to be expected, says Linas. "If you look around the school, you'll have the same transmission as you have outside in the community," he says. "It was a mathematical certainty that that was going to happen."

Controlling community spread isn't enough to prevent school-based outbreaks, as cases in Jerusalem have shown. One school, which reopened in May following closure in March, experienced an outbreak that affected 153 students and 25 staff members, for example.

A lack of effective mitigation strategies might have contributed to this outbreak, says Donohue. School reopening requirements included improved hygiene, the wearing of face coverings and social distancing, but a heatwave led to schools dropping face covering requirements, and using continuous air conditioning, which has been linked to virus spread in other settings.

Norway, on the other hand, is often held up as a success story. There, schools were closed in March, but began to reopen a month later, under a range of mitigation strategies. Children were taught in cohorts of no more than 15 individuals, and encouraged to regularly wash their hands and maintain a 1-metre distance from each other. Outdoor activities and learning were encouraged.

These case studies only hint at what might help keep transmission of the virus in schools low. Based on what we have learned about how the virus spreads, it makes sense to teach children in small groups, where they are able to maintain a degree of distance and are exposed to fewer people. Without increased budgets and staffing, that may require children to spend only part of the day at school, leaving parents to find childcare for more of the day and potentially exposing the children to more people, which defeats the purpose.

A child has her temperature taken at a school in London

DAN KITWOOD/GETTY IMAGES

Staggered arrival

It also makes sense to minimise the opportunity for crowds to form. That means staggering the arrival and departure times of students, and possibly allowing students to eat at their desks rather than in a busy cafeteria. Large halls can be utilised for socially distanced learning instead. Many schools are putting such measures in place.

"Those strategies can go beyond the walls of the school building into community spaces that are not necessarily being used right now, such as churches or public libraries or gymnasiums," says Donohue.

Different strategies might be appropriate for different age groups. Home learning, mask-wearing and physical distancing will be more difficult for young children, but might help minimise the risk of virus spread in older pupils, for example (see "Should children wear face coverings in school?", page 10).

Staff members who teach or work with older children could be provided with hospital-grade face masks, and potentially plexiglass shields, say researchers contacted by *New Scientist*. The problem is that it isn't clear how effective any of these strategies may be to prevent transmission in schools.

Janet Sinsheimer at the University of California, Los Angeles, and her colleagues are one of several groups

›

attempting to predict what might work best using mathematical models and computer simulations. The team assessed the impact of two broad types of strategy: to reduce the number of people each child interacts with on a daily basis, and to reduce the rate of transmission through strategies such as mask-wearing and distancing.

"Reducing class density has, in our models, a bigger impact," says Sinsheimer. "But both policies can make a difference."

Ideally, researchers would do randomised, controlled trials to learn what works, says Donohue. While the idea of experimenting in schools might not be popular, it is essentially already happening, she says. There are about 13,000 school districts in the US, each of which is developing its own guidance for schools. "There will be 13,000 approaches to these critically important decisions," says Donohue. "There is already experimentation going on, it's just not random – and we're not necessarily learning from that."

1.6 billion

Number of students affected by school closures globally

What is clear is that, even if the risks can be reduced, they will still exist. "There will not be a time in the foreseeable future that we will be able to say: there's no covid-19 in this building," says Linas.

Around the world, it is estimated that almost 1.6 billion children have been affected by school closures. Education isn't all they have missed out on.

Many children from low-income families rely on school meals for food. Children with extra developmental needs are often provided with expert care that parents alone can't reasonably be expected to provide. Many healthcare programmes are delivered through schools. And some 20 per cent of child abuse and neglect cases are reported by school officials in the US. "When schools don't have eyes on kids, that's going unreported and unaddressed," says Donohue.

The impact of missed education could be lasting. "If a child is not reading at grade level by the third grade, they are four times less likely to graduate high school," says Christakis. "And low-income children are six times less likely."

Donohue points to past studies on the impact of school closures triggered by wars and teachers' strikes. "We see the effects 30 years later, on children of all ages who miss school," she says. "Even a couple of months of missed school can translate into a reduction in earnings of somewhere between 2 and 3 per cent."

All of those contacted by *New Scientist* stressed that schools should prepare to make up for the lost months of education, offering more tuition as well as mental health support. Many suggested lengthening school terms, and keeping schools open during what would usually be holidays for the next year or so. "Otherwise we are doing a disservice to an entire generation of school children," says Donohue.

"It starts with recognising that this is a real problem," says Christakis. "Kids are paying a huge price. It's not just that they are missing school, their lives are being significantly affected as well." ■

Face coverings

Should children wear face coverings in school?

Days before schools reopened, the UK government reversed its advice that face coverings need not be worn by pupils in England. Now it recommends that secondary school children wear them in corridors and busy communal areas. Official advice on this has evolved during the pandemic.

Currently, the World Health Organization (WHO) advises that young people over the age of 12 wear face coverings as adults do, ideally wherever it is difficult to maintain a distance of at least 1 metre from others in places where coronavirus transmission is ongoing. This doesn't apply to people with certain disabilities, or those who find wearing a face covering anxiety-provoking.

For children aged between 6 and 11, the advice is more flexible. Whether a child wears a mask should depend on their ability to use one, according to the WHO, which also advises that children under the age of 5 shouldn't have to wear them.

SALLY ANSCOMBE/GETTY IMAGES

Guidelines vary on the age at which children should wear face masks

The American Academy of Pediatrics strongly recommends the use of face coverings by children age 2 and older. Public Health England, meanwhile, doesn't recommend face coverings for children under the age of 3 "for health and safety reasons", but it is unclear what those are. There is unlikely to be any risk to the breathing abilities of a young child who wears a face covering, say experts contacted by *New Scientist*.

The greater risk is likely to be that young children use masks incorrectly. "They might be taking them off, manipulating them, and putting them back on their face," says Dimitri Christakis at the Seattle Children's Research Institute. "It might actually be worse than wearing a mask."

There are also concerns that face coverings will affect the way young children learn about language, emotions and social interactions. "When they're learning sounds and words, and when their vocabulary is increasing, children and babies tend to focus [their attention] on the mouth," says Lisa Scott at the University of Florida.

The WHO urges that decision-makers consider the potential impacts of mask-wearing on learning and social development even in children aged between 6 and 11. Scott recommends that carers and teachers of young children wear see-through masks where possible to minimise such effects.

"I think we can help children cope and adapt, and learn to read emotions and social cues in other ways," says Julie Donohue at the University of Pittsburgh in Pennsylvania.

T-cells

Are more people immune to the coronavirus than we thought?

Clare Wilson

THROUGHOUT the coronavirus pandemic there have been fierce debates over the science – when to lock down, whether face coverings help and whether children are less susceptible, for example. The latest row is over whether we have been ignoring a crucial part of our immune response to the virus: T-cells.

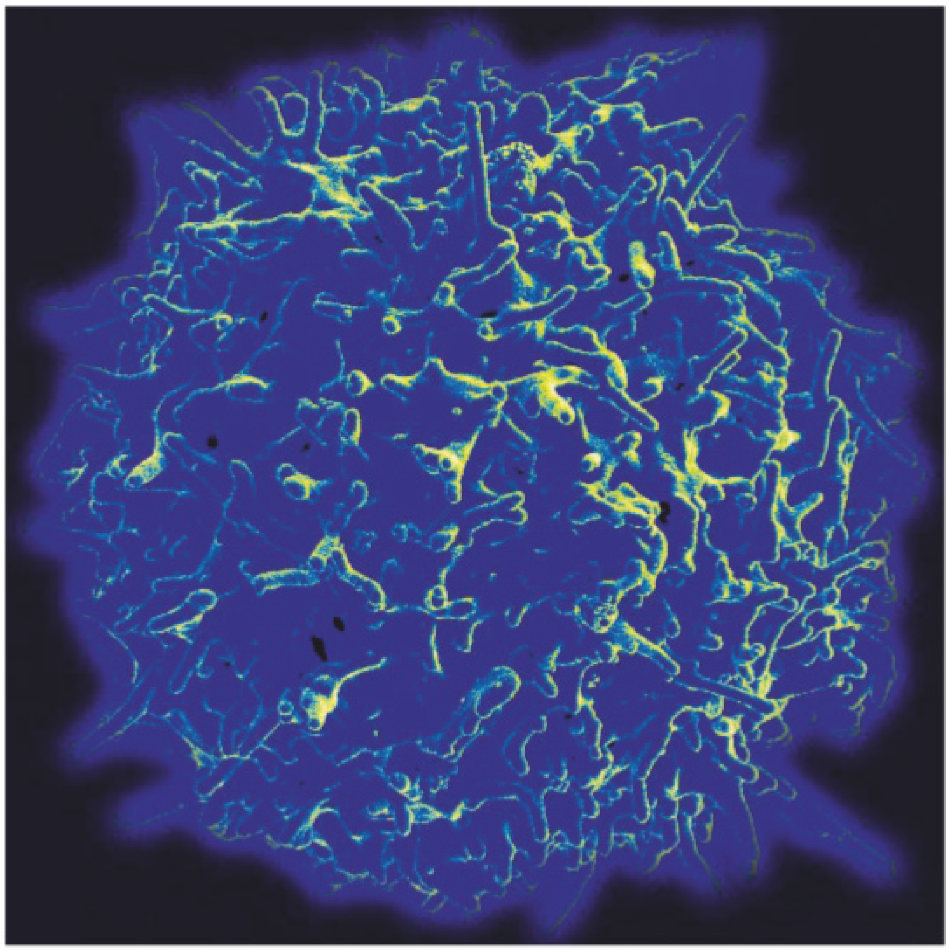
This matters because if people have more immunity to the virus than we thought, then perhaps we could abandon some covid-19 countermeasures. This was the case made by US President Donald Trump's newest adviser on covid-19, Scott Atlas at Stanford University in California. It has also been championed by others who argue against lockdowns. Is there any truth to the idea?

The immune system has two main arms to fight off pathogens such as the coronavirus. The one we hear most about consists of antibodies, small molecules that can recognise specific pathogens and target them for destruction.

Antibodies against the coronavirus can be measured in the blood and so surveys quickly began to gauge the proportion of people who have them. But even in places hit hard by the pandemic, antibody levels aren't high enough to give herd immunity, which occurs when enough people are immune to the virus that it can no longer easily spread.

Researchers have estimated that 65 per cent of a population would need to be immune to achieve herd immunity, based on how contagious the virus is. In London, antibody levels were about 10 per cent between 26 April to 9 August. For England as a whole, as with many European countries, it is in single digits.

These levels are widely taken as indicating how many people have been infected by the coronavirus. But the picture is more complex than this because of the second arm of our immune system, T-cells. Antibodies are sometimes seen as more important because they can stop viruses from entering the body. But once viruses make it inside, only T-cells can kill infected cells.


NIH/NATIONAL INSTITUTE OF ALLERGY AND INFECTIOUS DISEASES

A scanning electron micrograph of a human T-cell from a healthy donor

It takes a few days to obtain results for tests of T-cell activity against the coronavirus, compared with as little as 90 minutes for antibody tests, but a few groups have been testing on a small scale. They have found T-cells that react to the coronavirus in 10 to 50 per cent of people tested.

That doesn't necessarily mean that up to half the population is immune to covid-19, says Alessandro Sette at the La Jolla Institute for Immunology in California. Some of these studies, including one by Sette and his colleagues, looked at blood donations given before the current pandemic, to test for pre-existing immunity to the coronavirus. Others examined samples from people with covid-19.

The most likely explanation is that the pre-pandemic blood samples that tested positive were from people who had previously caught milder coronaviruses, such as the ones that cause colds, and their T-cells are reacting to the one that causes covid-19. It is probable, although by no means definite, that such people would get less sick with covid-19, but they could still get infected – and pass it on to others, says Sette.

"I have seen people using our data to say we should open up society. I definitely do not want that"

However, a Swedish study that tested about 200 people, including some known to have had covid-19 and their family members, found that those who had been sickest with covid-19 had more T-cell activity. This suggested it was directed against the current coronavirus, not old ones, says Marcus Buggert at the Karolinska Institute in Stockholm, who worked on the study. "But we can't say every single T-cell was induced by this new virus," he says.

Testing anomalies

As with antibodies, it is unclear how long T-cell immunity will last. "I have seen [people] using our data to say we should open up society. I definitely do not want that," says Buggert.

T-cells could explain some puzzling anomalies in antibody testing. "We have had people with confirmed cases of covid-19. Their antibody tests have come back negative, but their T-cells tested positive. That suggests antibody tests are not telling us the whole picture," says James Hindley at UK firm Indoor Biotechnologies, which has developed a relatively fast and simple T-cell test.

The firm's work hasn't yet been published, and its test has so far only been used on about 100 people. But Hindley's team has found a few people testing positive for T-cell activity whose spouse had confirmed covid-19, yet they themselves somehow avoided it, as far as they know. "It raises the question of whether the T-cells kept the virus at bay," says Hindley.

It is unlikely that questions such as these will be resolved until T-cell testing becomes much more common. Until then, says Hindley, the growing body of T-cell work should be seen as cause for hope – but not complacency. ▮

Interview

Covid-19 in the Central African Republic

Marie-Roseline Darnycka Bélizaire of the WHO tells **Jessica Hamzelou** about the challenges of fighting coronavirus in the face of limited resources

WHEN the new coronavirus began to spread around the world earlier this year, Marie-Roseline Darnycka Bélizaire of the World Health Organization (WHO) was heavily involved in the fight against Ebola in the Democratic Republic of the Congo (DRC).

She was recently relocated to the Central African Republic (CAR) to advise on and assist the country's response to covid-19.

Jessica Hamzelou: What was your first job on arriving in CAR in March?
Marie-Roseline Darnycka Bélizaire: When I arrived, I was posted within the ministry of health, which helped strengthen the relationship between the WHO and the country.

The starting point was to review the national preparedness and response plan. At the time, there were only around six confirmed coronavirus cases in the country. The response was already in shape – they had been preparing since January. One covid-19 treatment centre was already functional.

But we adapted the plan to several different scenarios that might present in the country. We proposed reinforcing the healthcare system. And we began systematic testing in the community to understand the transmission of the virus.

How did the systematic community testing pan out?
The strategy at the beginning was to test, isolate, treat and trace contacts. So far, around 1298 contacts have been diagnosed with the virus.

We had screening at the border and that was how we found that most of the early cases were being imported into the country. We tested all truck drivers entering CAR. If a driver tested positive, they were placed in isolation and underwent treatment.

WHO/LINDSAY MACKENZIE

Profile
Marie-Roseline Darnycka Bélizaire is a country preparedness and international health regulations officer for the WHO

How has the strategy changed since then?
In June, the number of community cases overtook that of imported cases, so we changed the strategy. We are limited in the number of tests that we can perform. So now we only give tests to people with fever or with flu or covid-19-like symptoms.

At the start of the covid-19 outbreak, you were based in DRC, aiding the response to Ebola. What was it like watching events unfold from there?
I was worried that the pandemic would come to DRC while we were in the final stages of the Ebola epidemic. I was also worried because some local communities believed that the team working on Ebola had introduced covid-19 to the country in order to stay for longer. We had to convince them that this was a worldwide outbreak, and not related to us.

Has the covid-19 pandemic affected efforts to control Ebola in DRC?
DRC has a new Ebola outbreak, but we can't say that covid-19 has increased Ebola. The pandemic can make the response to Ebola difficult, though. While both pathogens are dreadful and some preventative measures are the same, the speed of the spread of the viruses is very different, and requires a different approach.

What are the current challenges you face in CAR?
The behaviour of some people hasn't changed to avoid the spread of covid-19. People continue to hold street markets and attend funeral services, which are a very important part of the culture here, for example. People still don't want to wear masks.

Part of the community doesn't even believe in the existence of covid-19. Some are saying it is something invented by the government. And as we have a very low mortality rate here for covid-19 so far, the population doesn't see the risk of the disease.

How can you overcome those challenges?
We cannot easily change people's minds, but we are increasing awareness in order for them to understand that the disease is real, and that they are being exposed to major risks by not observing the preventative measures. We are working with community leaders and vulnerable groups who have a higher risk of dying, so those individuals can be aware and protect themselves.

Cases across Africa more widely seem to be lower than other parts of the world. Why is that?
The exponential increase in cases seen in the European region hasn't been observed in Africa. But as containment measures are eased, we expect more cases will be detected in areas that have previously been less affected.

Are you worried about the access that countries like CAR might have to an eventual vaccine?
While there are over 160 vaccine candidates in the pipeline and we are cautiously optimistic, we mustn't rely on a future vaccine to fight this pandemic. ▮

WHO/LINDSAY MACKENZIE

Marie-Roseline Darnycka Bélizaire at work in DRC during the Ebola outbreak

New
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Analysis Environment

Wildfires and hurricanes hit the US

Some states have been left struggling to cope by natural disasters almost certainly being fuelled by climate change, finds **Adam Vaughan**

ANDA CHU/MEDIANEWS GROUP/EAST BAY TIMES VIA GETTY IMAGES

California is experiencing another year of major fires

MORE than 5450 square kilometres have burned across California in the past two weeks, as firefighters continue to battle some of the state's worst wildfires, which have left seven people dead, and more than 100,000 evacuated. Meanwhile, the southern states of the US have experienced their first devastating hurricane this year.

The California fires include some that rank among the largest ever seen in the state. They followed a heatwave that caused blackouts, with Death Valley National Park hitting 54.4°C in August, the highest temperature ever recorded on Earth, pending verification.

"Exceptionally hot weather over the past two weeks certainly played a proximal role in drying out vegetation to this extreme degree," says Daniel Swain at the University of California, Los Angeles. But the drying of fuel also started earlier, he notes. Last winter was dry in north California, and spring brought heatwaves.

There are several unusual aspects to the current fires, even for a region used to intense blazes. They expanded dramatically in the absence of the usual driver for large and fast-moving fires in the state: powerful, dry winds. "That makes the enormous acreage burned in such a short time all the more astonishing, since they're essentially spreading on accord of their own intensity," says Swain.

The ignition of fires by dry lightning – thunderstorms without rain – is also rare for the region, says Stephen Pyne at Arizona State University. He says this is California's fourth major fire year in a row, when historically the state has seen between seven and 12 years between big fire seasons.

In the Gulf of Mexico, it is severe hurricanes that are the problem. Hurricane Laura made landfall in the US on Thursday 27 August amid official warnings of an "unsurvivable" storm surge, widespread flash flooding and catastrophic wind damage.

The storm is the first of four hurricanes in the Atlantic this year. About four-fifths of oil and gas production in the Gulf of Mexico has been shut, and losses of about $15 billion have been estimated. The energy heartland of the south-western US was previously battered by Hurricane Harvey in 2017. Researchers later found that the heavy rainfall from the storm was made three times more likely by climate change.

$15bn

Estimated losses to oil and gas industries from Hurricane Laura

Climate change is almost certainly at work in California too. "It is abundantly clear that climate change is increasing the likelihood and intensity of heatwaves in California," says Swain.

The vapour-pressure deficit (VPD), the difference between the amount of moisture in the air and the amount at which the air becomes saturated with water, is also higher than in the past 40 years across most of California, says Thomas Smith at the London School of Economics. "Higher VPDs are to be expected with climate change," he says.

Although the California Department of Forestry and Fire Protection had 14,000 people fighting the fires, observers say it is impossible to have enough crew to stop fires this big and dispersed. "California would have to become the fire equivalent of a police state," says Pyne.

In the short term, reducing the amount of fuel by thinning vegetation and forests is considered a key mitigation against future fires. Authorities last month agreed a five-year plan to do just that. With climate change locked in for the next 30 years, the longer-term answer is to reduce carbon emissions, says Smith. ▮

Technology

AI automatically removes unwanted objects from photos

Chris Stokel-Walker

AN IMAGE or video can be spoiled if there is a distracting object in the foreground, but a new artificial intelligence tool can help by digitally removing the unwanted obstruction. The AI can take out fences, raindrops and reflections in a window, and it might eventually be available on smartphones.

The idea came to Jia-Bin Huang at Virginia Tech University when he visited a zoo and was frustrated at his inability to get a good photo of the animals.

He and his colleagues developed their AI to clean up such images. Its neural network analyses several frames in a video, or in a "motion photo" taken by some smartphones, and identifies objects in the images. It then uses any slight change of angle between frames to calculate the distance to each object.

"When you move the camera, you'll find the motion for each layer will be different because they're at different depths," says Huang.

The algorithm then separates out the objects into different layers and removes the foreground layer, providing an unobstructed view of the objects behind (arxiv.org/abs/2004.01180).

Removing objects from images isn't new, but this method of doing so is. Rather than labelling certain features as things to be removed or not, the neural network automatically discovers the distracting foreground objects in the process of learning.

"What this paper does really well and nicely is to use the same approach to resolve multiple image-enhancement problems, like removing reflections from windows as well as a fence obstructing a view behind," says Dima Damen at the University of Bristol, UK, who calls it a "seminal paper in the field".

Huang hopes to make further improvements to the tool and to run it on smartphones. ▮

Cosmology

Travelling through a wormhole may actually be possible

Leah Crane

PHYSICISTS have worked out a way to send someone through a wormhole, a tunnel between two black holes that connects distant regions of space-time. Normally it would be impossible to pass through one, but factoring in an extra dimension might make it possible.

Under Albert Einstein's theory of general relativity, which describes the behaviour of gravity and space-time, most wormholes would either close whenever something falls in or be extremely small and disappear immediately.

Juan Maldacena at the Institute for Advanced Study in New Jersey and Alexey Milekhin at Princeton University have figured out how a traversable wormhole could exist while following all of the laws of physics as we know them.

They calculated that if there were an additional dimension of space-time, it would allow for a large number of quantum fields. Fluctuations in quantum fields can produce negative energy, which could keep the wormhole from collapsing (arxiv.org/abs/2008.06618). There is no evidence that all these extra fields exist, but they theoretically could, says Maldacena.

"There are two questions here, which are: whether you would expect this to occur naturally – and there the answer is almost certainly no – and also if you could expect a sufficiently advanced civilisation to be able to make it," says Aron Wall at the University of Cambridge. "It could, in theory, be made with mostly ordinary matter and quantum effects," he says. Whether that would be worth the effort is another question entirely, he adds.

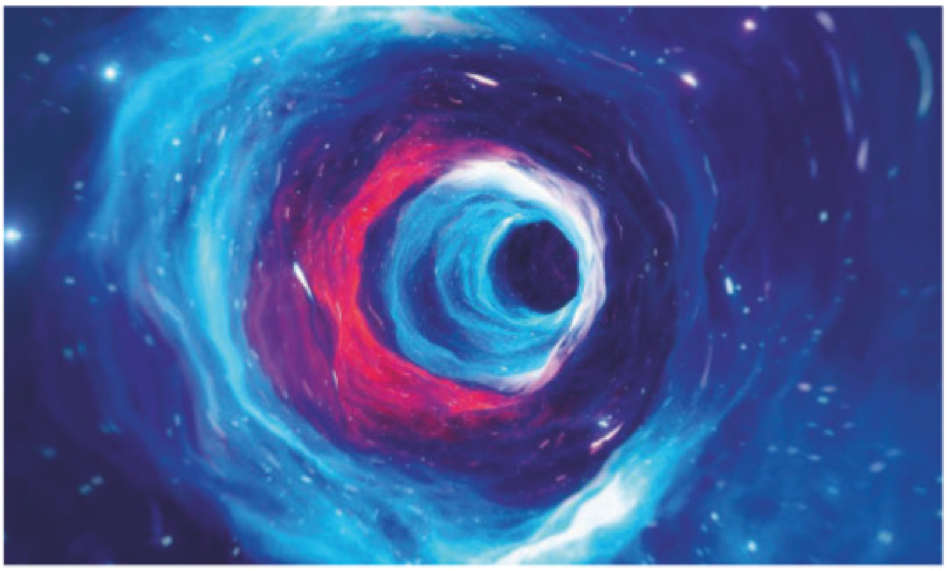
In order to be physically possible, travelling through a wormhole to a distant location would have to take longer than flying there directly through space at the speed of light. However, because of the effects of general relativity, time would pass differently for the person inside the wormhole. "It wouldn't take very long from the perspective of the person inside, while everyone they knew on the outside gets old and dies," says Wall.

Falling through the wormhole wouldn't be all that unpleasant, though, you would just slowly accelerate to extraordinarily high speeds, and then decelerate again when you emerge. "It'd be just like being in free fall – like there is a hole in the ground and you step in and just fall, and then 3 seconds later you'd emerge on the other side," says Don Marolf at the University of California, Santa Barbara.

Anything else that falls into the wormhole will also accelerate to nearly the speed of light. Unless the wormhole was thoroughly cleaned out and everything else blocked from entering it, falling in would mean certain death from high-speed collisions.

"Whenever you travel close to the speed of light, any particle or dust grain or anything that you hit will be problematic. Even a photon would cause you trouble," says Maldacena. "So that's a word of caution." ■

You could theoretically pass through a wormhole between two black holes



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Biofuels

Light-harvesting plastic helps algae convert more energy

ADDING a synthetic polymer to algae has increased the plant's rate of photosynthesis, which could lead to more efficient biofuels.

Less than 5 per cent of the sunlight absorbed by any plant is typically converted into energy. To make that process more efficient, Shu Wang at the Chinese Academy of Sciences and his colleagues fused a light-harvesting polymer with a species of freshwater green algae, *Chlorella pyrenoidosa*, which is commonly used to produce biofuel.

The team grew algae in a watery solution and added a polymer called PBF, which bonded to the surface of the algae's cells. PBF has a high rate of green light absorption, which led to increased rates of photosynthesis and the creation of more photosynthetic products such as oxygen and adenosine triphosphate (ATP), which carries energy in cells.

The experiment was mostly done in low light, but the team also tested the effect of brighter light on oxygen production. In the brightest light, the number of oxygen molecules produced increased by 12 per cent, compared with algae without PBF.

But under low-light conditions, the hybrid was more effective, leading to oxygen molecules increasing by 120 per cent and ATP molecules by 97 per cent. The maximum growth rate of the algae also increased by 110 per cent in low light (*Science Advances*, doi.org/d7jm).

Wang plans to test the method on other plants, and says it could make it easier to produce biofuels.

"This fantastic increase in photosynthesis rate is only seen under limited light conditions. It is less impressive under brighter conditions when the algae has reached its light saturation limit," says Richard Cogdell at the University of Glasgow in the UK.

"What I'd like to see is for these researchers to set up big ponds of algae, one with and one without this polymer, and really see the difference in efficiency under normal illumination," he says. ■

"This fantastic increase in photosynthesis rate is only seen under limited light conditions"

Jason Arunn Murugesu

Neuroscience

Tap in to your unconscious brain for a cognitive boost

Clare Wilson

HAVE you ever had a solution to a problem pop into your head, seemingly out of the blue? It could have been thanks to unconscious mental processes – and, in future, there might be a way to harness such brain activity.

Aurelio Cortese at the Advanced Telecommunications Research Institute International in Japan and his colleagues have trained people to learn a simple rule that they weren't consciously aware of, yet that subtly influenced their decision-making. "As far as I know, no one has [previously] directly shown that people can be trained to use their unconscious mind," says Cortese.

The process involved getting 18 people to perform a simple task while watching a screen inside a brain scanner. They then had to make decisions that required them to learn an arbitrary rule: that a pattern of unconscious brain activity associated with leftward motion would signal A and rightward motion would signal B.

SOVEREIGN, ISM/SCIENCE PHOTO LIBRARY

Our unconscious mind has hidden depths that we may be able to harness

First, the team trained an algorithm to recognise each participant's corresponding brain activity for the two types of motion. They spent an hour watching patches of dots moving either left or right, while their brains were scanned.

After this, the human training began. For this, the participants were shown dots moving around randomly and the computer read their brain activity, as before. Even though there was no true direction of motion to perceive, their randomly fluctuating brain activity sometimes matched what it would have been if the dots were actually moving left or right.

Then participants were asked to choose between two options, A or B. If they picked the "correct" option – corresponding to their unconscious brain activity signalling left or right, as appropriate – they got a small cash reward, of 30 yen (£0.21).

Although they weren't told that leftward motion meant A and rightward B, they started to unconsciously learn this rule. Over about 200 trials, they started picking the correct response more often – 54 per cent of the time on the second day on average (*Nature Communications*, in press).

This was only a little better than chance, but "the very fact that they could go above 50 per cent was interesting", says Cortese. "There's no way that they can perform above chance if they have no access to the information."

Some participants got it right about 65 per cent of the time by the end. Cortese thinks they were better at accessing their unconscious mental processes. "With more training, we'd expect the effect size to increase," he says.

People were also asked to state which way the randomly moving dots were going. Their guesses didn't correspond to their unconscious brain's "choice", showing they weren't consciously aware of it, says Cortese.

The researchers hope that giving people this kind of training will help in problem-solving or creative activities, where unconscious mental processes play a role. They are about to start trying this out with artists.

"What we are consciously aware of is a very small part of the space of information being represented in the brain," says Stephen Fleming at University College London. "This study shows us we can extract some of that information and then use it – it's pretty compelling."

Cortese's group has previously shown that using this kind of brain scanning can reduce people's fear of certain animals, by rewarding them for unconsciously thinking of those creatures. ▮

Quantum computing

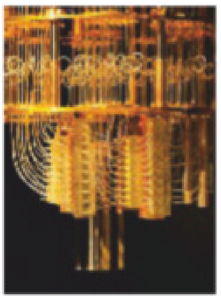
Cosmic rays could destroy quantum computers

RADIATION from space may be a big problem for quantum computers. Cosmic rays can disturb their fragile inner workings and limit the kinds of calculations they may one day do.

Quantum computers are made of quantum bits, or qubits, which store and manipulate quantum information. One of the most important factors for qubits is the coherence time, the amount of time a qubit can stay in a particular state.

"The longer you have, the more calculations you can do, the more complex the calculations, and the more reliable those calculations are," says Brent VanDevender at the Pacific Northwest National Laboratory in Washington state.

He and his colleagues used two qubits to test how radiation in the environment affects the coherence time of a type of qubit based on superconductors. Superconductors carry charge with pairs of electrons, but previous experiments have shown that those pairs are split apart far more often than expected, which lowers coherence time.


IBM

The fragile states of qubits inside quantum computers can be disturbed by space radiation

The researchers found that background radiation, both from natural nuclear decay and from cosmic rays, can account for all those extra broken pairs of electrons (*Nature*, doi.org/d7jp).

Right now there are other sources of noise that are more prevalent, they say, but as quantum computers get better over the next decade, this could be a limiting factor. Some radiation can be stopped by using a lead or concrete shield around the computer or placing it underground.

However, if quantum computing is to become more widespread, the idea of putting all the computers underground "starts to get ludicrous and becomes an argument for other kinds of qubits", says VanDevender. Instead, he and his colleagues are working to make qubits that can tolerate a few broken electron pairs without losing their coherence. ▮

Leah Crane

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Climate change

Billionaire geoengineering

Rich philanthropists are funding research into altering the oceans in an effort to combat climate change. How far should they go, asks **Mark Harris**

SOME of the world's richest people are funding research that could use the oceans to combat climate change. The idea is welcomed by some researchers, but others caution that there is a lack of international agreement about geoengineering the planet in such ways. Should billionaires be able to start tinkering with the climate without asking the rest of us?

Last September, scientists, policy-makers and funders met in California to discuss an idea to use an emerging suite of technologies known as ocean alkalinity enhancement (OAE). This aims to reduce both ocean acidification – which threatens delicate ecosystems like coral reefs – and atmospheric carbon dioxide levels (see "How to save the seas", right).

Doing this on a planetary scale would be a gargantuan undertaking. A report from the conference says that one OAE process requires the extraction of 5 billion tonnes of rock each year, twice the quantity used in global cement production today.

The rock would have to be finely ground up to increase its reactive surface area, and ultimately deployed worldwide, perhaps via a fleet of ships. This would have its own significant carbon footprint, making calculating the eventual benefits fiendishly complicated.

Silent benefactor

The conference attendees, including ecologists, biochemists and experts in carbon removal, discussed these problems, and brainstormed the science, the systems and the cash needed to make OAE a reality.

Little did most of them realise that the organisation behind the conference, Oceankind, is likely to be controlled by a Silicon Valley billionaire who would be able to fund a significant geoengineering effort out of their own pocket.

INAKI RELANZON/NATUREPL.COM

Ocean alkalinity enhancement could save the Great Barrier Reef

Oceankind was founded in California in April 2018, as a limited liability company (LLC). Incorporating as an LLC rather than as a non-profit organisation has one great advantage: charities in the US have to file public financial documents each year with the Internal Revenue Service, but LLCs are virtually opaque to public scrutiny.

Filings show that Oceankind's address is a post office box, and its named manager is Rosewood Family Advisors, a California-based firm whose accountants and lawyers provide dedicated services to ultra-affluent families.

It is unclear exactly who is funding Oceankind – neither Oceankind nor Rosewood responded to communications from *New Scientist* – but it seems to be someone who has made a lot of money in the tech industry.

Oceankind's first CEO was Evan Rapoport, a long-time Google employee who helped launch Google Street View before moving to the company's cutting-edge X team to develop underwater sensors for fish farming. Rapoport wouldn't discuss Oceankind, nor its benefactor, citing non-disclosure agreements. However, his LinkedIn profile reads: "I was recruited by a high net worth family in Silicon Valley to create a vision and strategy for their new foundation to bring 'moonshot thinking' into ocean conservation." Similar language on his personal website refers to an "ultra-high net worth" Silicon Valley family.

5bn

tonnes of rock will be needed per year for geoengineering oceans

At a food conference last year, Rapoport said that he hit the ground running, interviewing more than 100 experts and leaders across conservation, ocean engineering and food production. He said he was looking for "high-risk, high-reward, long-term impact that met the giving profile of the principals".

Rapaport reported that one of Oceankind's early projects was in lab-grown seafood, funding scientists to "immortalise" the cell lines for a few key food species, a process of manipulating cells so that they can be artificially grown for prolonged periods.

Oceankind also began to make donations to charities. WildAid in San Francisco noted in its 2019 annual report that it had received at least $100,000 from Oceankind,

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helping its efforts to boost well-enforced marine protected areas. More recently, it hired an AI expert to explore using machine learning in ocean conservation.

In 2019, Oceankind hired an environmental consultancy in California to convene the OAE conference. "We were all a bit mystified about where the funding for the conference was coming from," says one of the attendees, who weren't informed who was behind Oceankind. "A number of scientists were concerned that it was fossil fuel money, and we were told it was not."

The conference was intended to summarise the science, share insights about OAE's effectiveness, risk and uncertainties, and discuss opportunities to advance the field.

"If we're really serious about solving our global carbon dioxide problem, it's unwise to ignore 70 per cent of the Earth's surface," says Greg Rau, a marine research scientist at the University of California, Santa Cruz, who attended the conference. "The geologic carbon cycle is very effective at moderating CO_2 over millions of years. Now we need to see if we can effectively accelerate that process, in ways that are cost-effective, safe and scale up."

Conference attendees agreed on several recommendations, with price tags. For those with less than $5 million to spend, the attendees suggested improving our understanding of OAE's ecological impact, building a community of practitioners or analysing the costs of different technologies. More ambitious projects over $10 million included assessing market incentives and policy levers to enable OAE at scale and educating the public.

For ventures with more than $20 million at their disposal, the conference recommended developing OAE technology to reduce its costs to below $50 per tonne of carbon removed. Swiss start-up Climeworks currently charges $1100 to permanently sequester 1 tonne of CO_2 using its air capture system.

> "If we're serious about solving climate change, it's unwise to ignore 70 per cent of the Earth's surface"

The conference even suggested that very wealthy donors consider "large-scale demonstrations" to validate the effectiveness of OAE. Oceankind's website similarly talks about working "at scale", indicating a desire to think big.

Silicon Valley has no shortage of billionaires who could easily afford to carry out huge projects. "Corporations and rich people have realised that government has not come through on doing the heavy lifting for carbon management," says Rau. "People that have the interest and have big money are stepping up."

Bill Gates, for example, has long publicly funded research into geoengineering, including plans to use stratospheric particulates to reflect incoming sunlight and slow global warming.

More recently, US payments company Stripe pledged to spend at least $1 million annually to remove CO_2 from the atmosphere.

One of Stripe's first purchases in this area is intended to capture more than 3000 tonnes of CO_2 with Project Vesta. This aims to use natural wave action on an unnamed Caribbean island to accelerate the weathering of the alkaline mineral olivine, which then reacts with CO_2.

Stripe's billionaire CEO Patrick Collison is also personally funding a similar effort, Project Green Fuse, at Heriot Watt University in Edinburgh, UK, *New Scientist* has learned. This will test wave action on olivine, initially under lab conditions, although experiments have been delayed by the coronavirus pandemic.

How to save the seas

Ocean alkalinity enhancement (OAE) aims to increase undersea storage of carbon dioxide.

The simplest method involves accelerating the weathering of alkaline, silicate rocks. When such minerals are exposed to carbon dioxide in water, they react to produce dissolved calcium and magnesium bicarbonates.

Shellfish and other creatures use these bicarbonate ions to form skeletons and shells. When the sea creatures die, their bodies sink to the ocean floor. Over time, layers of shells and sediment cement together and turn into rock, stably storing the carbon.

OAE seeks to accelerate this process by grinding alkaline rocks to increase their reactive surface area. The ground-up rocks could be spread on land to react with CO_2 in rainwater, and eventually find their way via rivers to the sea.

Other schemes involve deploying the rocks at coastlines to benefit from extra grinding from waves, or dumping them in the middle of the ocean.

Another OAE plan envisages coastal chemical reactors that use high concentrations of CO_2 captured directly from cement plants or power stations to accelerate the process further.

Just as there is very little international consensus on how or even whether to proceed with geoengineering, there is virtually no way to stop a state, or a billionaire, trying to modify the climate. "Most people agree that the governance mechanisms are mostly not there," says Elisabeth Graffy at Arizona State University.

Avoiding red tape?

Any organisation hoping to push ahead with geoengineering activities, even on a small scale, would be expected to engage with multiple bureaucracies at national, state and local government levels, she says. Of course, Silicon Valley is known to act first and deal with regulatory issues later, so it wouldn't be unusual for someone with that background to push on without asking.

"It's always appealing to say, 'Wouldn't it be great if someone could just do something and get past all the red tape?'," says Stephen Gardiner at the University of Washington, Seattle, author of *A Perfect Moral Storm: The ethical tragedy of climate change*.

"You could see that as a great statement of freedom. But the worry is that it's freedom without accountability, freedom that involves a great concentration of power for people who don't have the political legitimacy to exercise it," says Gardiner. "These are issues that ought to be discussed and of which the public should be aware."

In July, Democrats in the US issued a climate crisis action plan that included support for research on the risks and governance of geoengineering, ahead of a National Academies study on the topic later this year. If Oceankind has its way, they might find that a billionaire has got there first. ■

JOE RAEDLE/GETTY IMAGES

US election

Voting by mail has little effect on US election results

NEITHER the Republicans nor the Democrats would gain an advantage in US elections if everyone voted by mail, according to a new analysis.

The debate surrounding postal voting has come to a boil this year, as the US determines how to hold a presidential election in the midst of the coronavirus pandemic. Voting by mail has been put forward as a solution, but President Donald Trump has claimed it would result in voter fraud and give his Democrat opponents an unfair advantage.

Michael Barber at Brigham Young University in Utah and John Holbein at the University of Virginia have devised a model to look at the effect of voting by mail, by combining county-level voting data from 1992 to 2018 with US census records.

By 2018, 175 of the 3100 or so counties in the US had switched at least partially to staging their elections by postal vote.

The pair modelled how election turnout and party vote shares morphed as counties switched to postal votes and estimated what would happen to an average county.

The model showed that giving everyone a postal vote would increase county turnout by 2 per cent and that the Democrats would have a non-statistically significant increase in vote share of 0.7 per cent. Barber and Holbein say mail-in voting would have no significant effect at a national level either (*Science Advances*, doi.org/d7jb).

Due to the pandemic, at least three-quarters of US voters will be eligible to receive a ballot in the mail, according to an analysis by *The New York Times*.

Jason Arunn Murugesu

Health

Body fat tweak helps mice keep weight off

WHITE fat cells can be turned into energy-burning brown fat using CRISPR gene-editing technology. These engineered cells have helped mice avoid weight gain when on a high-fat diet, and could one day be used to treat obesity.

Human adults have plenty of white fat, the cells filled with lipid that make up fatty deposits. But we have much smaller reserves of brown fat cells, which burn energy as well as storing it. People typically lose brown fat as they age or put on weight. While brown fat seems to be stimulated when we are exposed to cold temperatures, there are no established methods of building up brown fat reserves.

Now, Yu-Hua Tseng at Harvard University and her colleagues have used CRISPR gene-editing to give human white fat cells the properties of brown fat.

Tseng's team used CRISPR to target a gene for a protein called UCP1, which is expressed in brown fat. "Its function is basically to turn chemical energy into heat," says Tseng. The resulting cells produced almost as much UCP1 as typical brown fat cells and had more energy-generating mitochondria than typical white fat cells. The team calls them human brown-like cells, or HUMBLE cells.

Tseng's team then transplanted either white fat, brown fat or HUMBLE cells into mice bred so they wouldn't reject human tissue. All the mice were fed a high-fat diet. Over 12 weeks, the mice given white fat cells gained more weight than mice transplanted with either brown fat or HUMBLE cells (*Science Translational Medicine*, doi.org/d7k5).

It might one day be possible to treat people with obesity or metabolic disorders by removing a small amount of their white fat, engineering it to be like brown fat and reimplanting it, says Tseng.

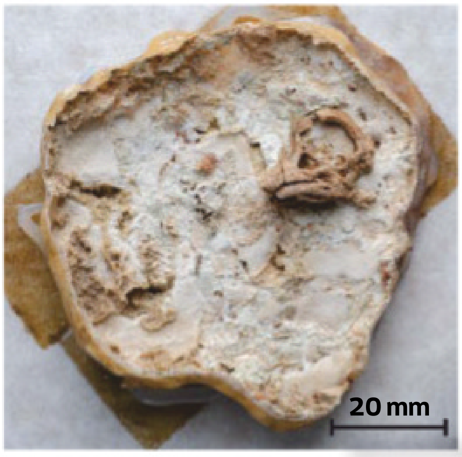
Jessica Hamzelou

Palaeontology

Baby titanosaurs sported nose horns

THE largest dinosaurs were long-necked plant-eaters called titanosaurs. Now, a fossilised embryo suggests that young titanosaurs had horns and forward-facing eyes – neither of which have been seen on an adult.

Martin Kundrát at Pavol Jozef Šafárik University in Košice, Slovakia, and his colleagues have studied the skull of a titanosaur embryo preserved in a fragment of eggshell from Argentina. The embryo still had the bones in their original places.



MARTIN KUNDRAT

The eye sockets were pointing forwards, whereas the skulls of adult titanosaurs have side-facing eyes. There was also a sharp horn on the snout, facing forwards (*Current Biology*, doi.org/d7k2).

It could be a new species of titanosaur, says Kundrát. But he thinks it is more likely that juvenile titanosaurs looked different to full-grown titanosaurs.

Whereas adults – which could weigh more than 30 tonnes and be 37 metres long – lived on open plains, Kundrát suspects the young lived in forests. Binocular vision would have helped spot predators or prey. The horn could have been a defence mechanism.

Adult, herd-living titanosaurs would benefit from seeing what was happening at their sides, says Kundrát. The horn would be unnecessary, because their main defence against predators was their size. **Michael Marshall**

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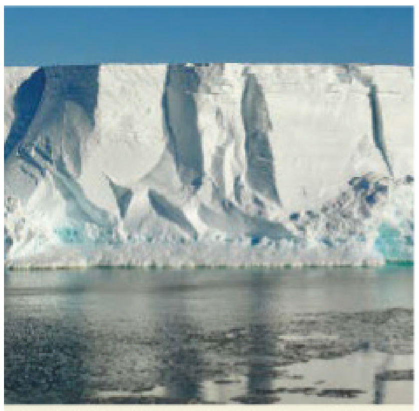
Really brief


SHUTTERSTOCK/DALE LORNA JACOBSEN

Meltwater might fracture ice shelves

Most of the ice shelves buttressing Antarctica's ice sheets risk fracturing as meltwater trickles into cracks on their surface. Such meltwater may have helped trigger the collapse of the Larsen B ice shelf in 2002, and could have major consequences for sea level rise in future (*Nature*, doi.org/d7hg).

Sticky solution to lactose intolerance

A glue that coats the inside of the intestine when swallowed could help treat lactose intolerance. Tests in pigs show that, when enhanced with an enzyme that digests lactose, the glue leads to a 20-fold improvement in the pig's ability to process milk (*Science Translational Medicine*, doi.org/d7hd).

Bacteria survive three years in space

Radiation-resistant bacteria can survive in space for a long time. The microbes endured being strapped to the outside of the International Space Station for three years, suggesting that they could travel between planets on asteroids (*Frontiers in Microbiology*, doi.org/d7hf).

Technology

An army of a million microscopic robots

TROOPS of mini walking robots have been created that could enable scientific exploration at a microscopic level.

People have made microscopic robots before, but these haven't been able to move by themselves, says Marc Miskin at the University of Pennsylvania. That is partly because of a lack of small enough actuators, which are required for movement, such as bending a leg. Miskin and his colleagues have developed an actuator made of a thin layer of platinum. The robots have four tiny actuators as legs, each connected to a different solar cell on the back. This enables the legs to bend if the solar cells are hit by laser light and propels the square metallic bodies forwards (*Nature*, doi.org/d7kt).

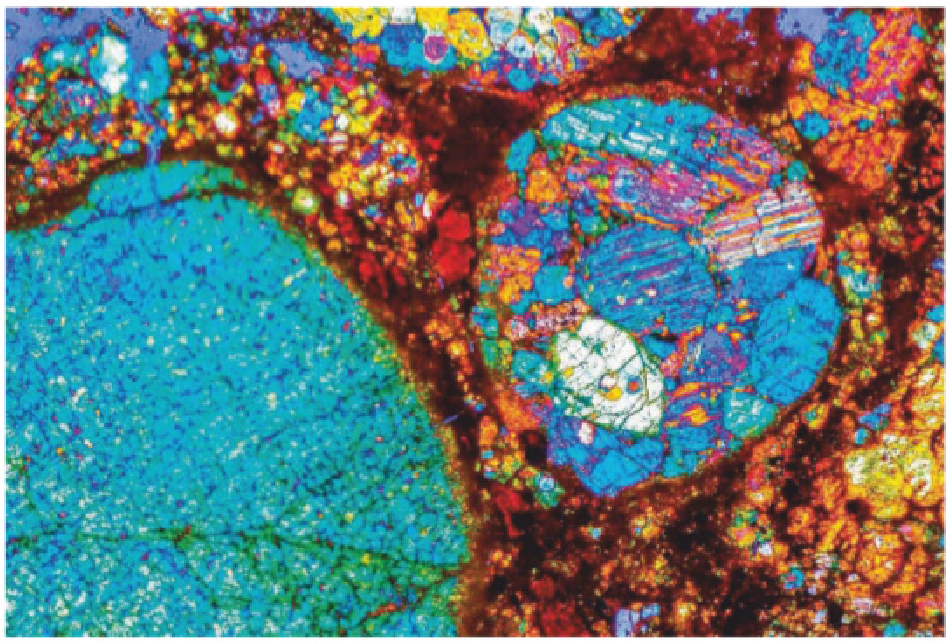
By shooting the solar cells in sequence with a laser, you trigger the legs to contract to move in the way you want, says Miskin.

Through a process similar to that used to produce circuit boards, Miskin and his team made more than a million microrobots, each of which is smaller than a tenth of a millimetre and only visible under a microscope.

The robots are only able to walk around, but Miskin says they demonstrate that we can develop and mass-produce microrobots with onboard electronics. The next step will be to incorporate functions, like sensing capabilities and programmability, he says.

The bots are small enough to be injected through a hypodermic needle and are made from biocompatible materials, so could potentially roam inside the human body. **Layal Liverpool**

Planetary science


ALFRED PASIEKA/SCIENCE PHOTO LIBRARY

Earth may have formed with enough water to fill the seas

AN ANALYSIS of meteorites from the inner solar system hints that water may have arrived along with the rocks that formed Earth.

According to some models, early Earth should have been dry, because the young sun was too hot to allow much ice or liquid water to stick to the rocks that eventually formed Earth and the other inner planets.

Meteorites called enstatite chondrites (a light micrograph of a slice of one is pictured above) are similar to those pre-Earth rocks. These meteorites were thought to be dry, but now Laurette Piani at the University of Lorraine in France and her colleagues have analysed 13 of them and measured their hydrogen content as a proxy for water. The rocks were wetter than expected, with the equivalent of 0.08 to 0.54 per cent water by weight (*Science*, DOI: 10.1126/science.aba1948).

"These meteorites are one of the best analogues we have for Earth's building blocks," says Piani. "This water was probably in the building blocks over the whole formation process of Earth."

If Earth was built from such rocks, they could have provided about three times as much water as fills the planet's oceans now, and Mars, Venus and Mercury could also have been wet when young. Leah Crane

Cell biology

Cells navigate through Hampton Court maze

GENERATING chemical gradients lets cells predict the fastest route through a maze – or a body.

It was known that cells can steer short distances by sensing and moving towards nearby attractive chemicals, or "chemoattractants", but how they navigate long routes through the body has been unclear.

Robert Insall at the Beatson Institute for Cancer Research in Glasgow, UK, and his colleagues have now studied the paths cells take through mazes. The cells picked a route by using enzymes to break down chemoattractants, then sensing the extent to which the chemicals are replenished.

"They read the resulting chemical gradients to see where to go," says Insall. This allows cells to tell the difference between dead ends and clear paths, because fresh chemoattractant only returns along clear paths, he says.

This strategy let mouse cancer cells and soil-dwelling amoebas rapidly solve mazes made of silicone, including a mini replica of the hedge maze at Hampton Court Palace in the UK (*Science*, DOI: 10.1126/science.aay9792).

"Cells are better at solving these mazes than people because they can sniff out a path before even going in," says Insall. **Alice Klein**

Welcome to our Signal Boost project – a weekly page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **Tree Aid**

Grow a greener future

For communities in the African drylands, the climate crisis is not a future threat but a daily reality. The effects of deforestation, desertification and a changing climate are widespread. There is clear evidence that temperatures are rising. A shorter rainy season is now a reality, and droughts and floods are becoming more frequent and severe. Forest resources are depleting faster in the drylands of Africa than elsewhere in the world.

Our strategy lays out ambitious plans to grow over 8 million trees in 5 years and to support 2.5 million people through poverty-alleviating initiatives.

These initiatives are rooted in the power of trees. The trees we grow enhance soil quality, improve harvests, protect from wind and flooding, support ecosystems and increase biodiversity. We provide people with essential training on Farmer Managed Natural Regeneration. They can utilise this training to encourage tree growth from degraded land and shrub vegetation. Additionally, we train communities in soil and water conservation techniques. This means that families can increase their land's resilience to drought and climatic stresses. In one project in Ghana last year, we worked with local communities to plant 898,368 trees along the Daka River.

Local small business enterprise has a vital role to play in combating climate poverty. We support people to form Village Tree Enterprises (VTEs). The members of these VTEs protect trees and work together to turn the tree products into nutritious food and goods, such as shea butter and moringa powder. By providing training, processing equipment and access to new markets, we can empower families and communities to grow their way out of poverty. These groups are particularly important to women, who often have limited access to resources.

Since 1987, TREE AID has planted more than 18.5 million trees. But there are significant challenges facing the people we work with, and we need your support to fight the climate crisis and poverty together.

Want to help?

Your support will help to build resilience to a changing climate, reverse the growing desert and empower communities to reclaim the land for themselves and their future generations. Visit **treeaid.org.uk/support-us/donate**

The columnist
James Wong looks into claims of toxic fruit and veg **p24**

Letters
How tough should we be on vaccine deniers? **p28**

Aperture
Colourful swirls of phytoplankton off Sweden's coast **p30**

Culture
Two books reveal the reality of life for an astronaut **p32**

Culture columnist
Star Trek is having a renaissance, says **Emily Wilson** **p34**

Comment

Halting drink-driving

We are on the cusp of cars that stop people driving while intoxicated. Embracing the technology will save lives, says **Amie Hayley**

MICHELLE D'URBANO

THE message couldn't be clearer: don't drive under the influence of alcohol or drugs. Yet people still put themselves and others in danger by getting behind the wheel while intoxicated. Despite decades of education programmes and law enforcement, road collisions attributable to intoxicated driving remain unacceptably high. We need a better approach and we are in the middle of a technological boom that may just deliver one.

Seat belts and airbags have dramatically reduced the number of lives lost on roads. However, they do little to prevent the cause of crashes. Someone dies every 25 seconds globally due to road traffic injuries, and one in five of the drivers involved will test positive for alcohol following the collision.

Some cars already have intelligent driver monitoring systems that help to reduce deaths by human error, such as inattention. These use cameras to monitor drivers' alertness. When there is a deviation from the behaviour it has been trained to recognise, such a system can either warn the driver or take complete control of the vehicle to stop a collision from occurring.

These systems may reduce collisions by up to 20 per cent. Already, they must be installed in all new European vehicles. In 2024, they must be included in all new US vehicles. Australia and New Zealand will also follow suit.

Now, a second wave of intelligent driver monitoring technology is on its way. Internal cameras can be combined with other biometric sensors, such as heart rate monitoring or skin conductibility, to determine a driver's internal state in real time. In other words, a car could determine when its driver is impaired by drugs or alcohol.

These technologies can already spot certain behaviours that are hallmark features of intoxication. For example, alcohol significantly impairs alertness and attentiveness, which such systems can detect, and the more someone drinks, the more pronounced these effects are.

Therefore, it might be possible to retrain such systems to identify and monitor the individual "impairment signature" for a range of other substances that are known to negatively affect driving. Ideally, this information would be used to automatically block the person from driving.

My colleagues and I are working to develop this technology. The first stage is to capture the exact signature of different drug types and characterise their effects on eye movements and driver behaviour. Then we can train the technology to efficiently identify these patterns.

Right now, my research group is determining the unique impairment signature for drivers intoxicated by amphetamines, benzodiazepines or alcohol.

Creating individual profiles will help to differentiate between a driver who has taken legal prescription drugs needed to treat a medical condition, such as benzodiazepines for anxiety, and someone who has consumed illegal drugs, such as methamphetamine.

Some people may ask: "But won't cars be driving themselves, anyway?"

It is true that semi-automated vehicles are on track to be legalised in the UK as early as next year, for instance. But although these systems can control a car's movements, they require an alert and capable driver to take over if needed. Fully driverless technology is still a long way from being realised.

In the meantime, driver-state monitoring systems will help stop crashes by ensuring that a driver is fit to be behind the wheel.

Over the next decade, these technologies could vastly reduce the number of traffic collisions. If we embrace them, we may finally be able to stop deaths linked to intoxicated driving. ■

Amie Hayley is at Swinburne University of Technology in Australia

#FactsMatter

A taste for danger

There are claims online that most of the fruit and veg we eat is toxic. Though there is some truth to this, it doesn't mean you should stop eating your greens, writes **James Wong**

AFTER decades of celebrating the benefits of fruit and veg, some corners of the foodie media are voicing a radical new claim: fresh produce is not only unnecessary for human health, it is actually quite toxic. With countless devotees, this school of thought argues that most plants have evolved elaborate toxins to defend themselves from predation, which makes animal-based foods the safer and healthier choice.

One statistic circulating on social media is that 98.8 per cent of plants are toxic whereas 99.9 per cent of animals are edible. As strange as it may seem, this narrative – at least, when it comes to plants – has a bit of truth to it, although that doesn't mean you should stop eating plenty of fruit and vegetables. So let's unpack the botany behind this claim.

Unlike animals, plants can't run away or hide from threats, so they use a different strategy: chemical weapons. They pack their cells with pungent, bitter-tasting compounds, caustic irritants and deadly nerve toxins to inflict damage on predators, humans included. This isn't just exotic plants in far-off jungles either – in fact, a whole range of ordinary edible crops belong not only to the same genus, but even the same species as some proper toxic ones.

Potatoes, courgettes and pumpkins are filled with such substances in the wild, and it was only after millennia of brilliant breeding work by the indigenous peoples of the Americas that they were rendered edible. Every now and then, some plants revert to their wild ways, meaning home growers can be poisoned by the cucurbitacins found in improperly grown courgettes, for example. You could add everything from carrots and rhubarb to kidney beans and nutmeg to the "toxic crops" list too, with literally hundreds of everyday examples. So how prevalent is this toxicity?

Well, when you start digging, things turn out to be quite complex. There are 300,000 to 400,000 plant species on Earth, of which roughly 50,000 to 80,000 are edible. That means between 12.5 per cent and 27 per cent of plants are edible. The huge range of estimates is because there isn't a clear-cut way of defining what counts as edible.

There is, after all, a difference between technically edible (think of the pine bark and mosses once ground into bread during times of famine) and popularly eaten (the wheat, rice and corn that make up 60 per cent of the plant-based calories we consume worldwide). Plus, with thousands of plants being newly recorded by science every year, we don't even know how many plant species are out there, hence the varying estimates. Tricky stuff.

> "Compounds made by broccoli as a toxic defence against insects are also what give it many of its nutritious effects"

However the numbers are crunched, though, I have yet to find any evidence behind the claim that 98.8 per cent of plants are toxic. I suppose the argument is that many of the plants we already eat use such defences, and so "edible" and "toxic" may not be mutually exclusive terms. So how do we define what is and isn't edible?

Despite us often talking about toxicity as if it is a strict either/or concept, the lines are actually more than a little blurry. The reality is that it is entirely dose-dependent. Water and even oxygen can be deadly when consumed to excess, despite being essential for life. The same is true for many of the substances plants produce to tackle bacteria, fungi and insects, which can actually have the opposite effect in our bodies.

The sulphur compounds produced by broccoli as a toxic defence against insect attacks are the exact same ones that seem to help give the vegetable many of its nutritious effects in humans, for example. The beta-carotene that makes an excess of carrot juice a bad idea is also converted into vitamin A by the body, which is essential to our survival in the correct amounts.

Even determining the dose at which these compounds become problematic is tricky. For many plants, the only sure-fire way to do this would be to run large clinical trials that intentionally poison hundreds of people to establish the exact safe dose, so we instead rely on quite arbitrary estimates based on limited evidence from accidental poisonings and animal studies. As a result, what is legally considered an unsafe level of bitter almonds or cherry extract in some countries is perfectly permissible in others.

This huge level of complexity means that the toxic and edible labels are largely cultural constructs in many cases. As such, creating an extreme narrative based on these terms is very easy to do and still technically correct, though very misleading.

Fortunately, we have decades of consensus from scientific studies, consistently showing that people who consume higher levels of fruit and vegetables tend to also enjoy far better health outcomes, which would be rather a surprise if they were really so toxic. ▮

James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, he shares his tiny London flat with more than 500 houseplants. You can follow him on Twitter and Instagram @botanygeek

James's week

What I'm reading

I have downloaded a copy of a Victorian houseplant book called Window Gardening. *Quite when I will get time to read it, I am not sure.*

What I'm watching

The new season of The Umbrella Academy. *Don't you judge me.*

What I'm working on

I am currently filming a new documentary series for the BBC on food and farming.

This column appears monthly. Up next week: Chanda Prescod-Weinstein

A feast of learning for children…

AQUILA Children's Magazine has a brilliant recipe for home learning that's sure to delight young readers who are missing their friends and teachers this summer.

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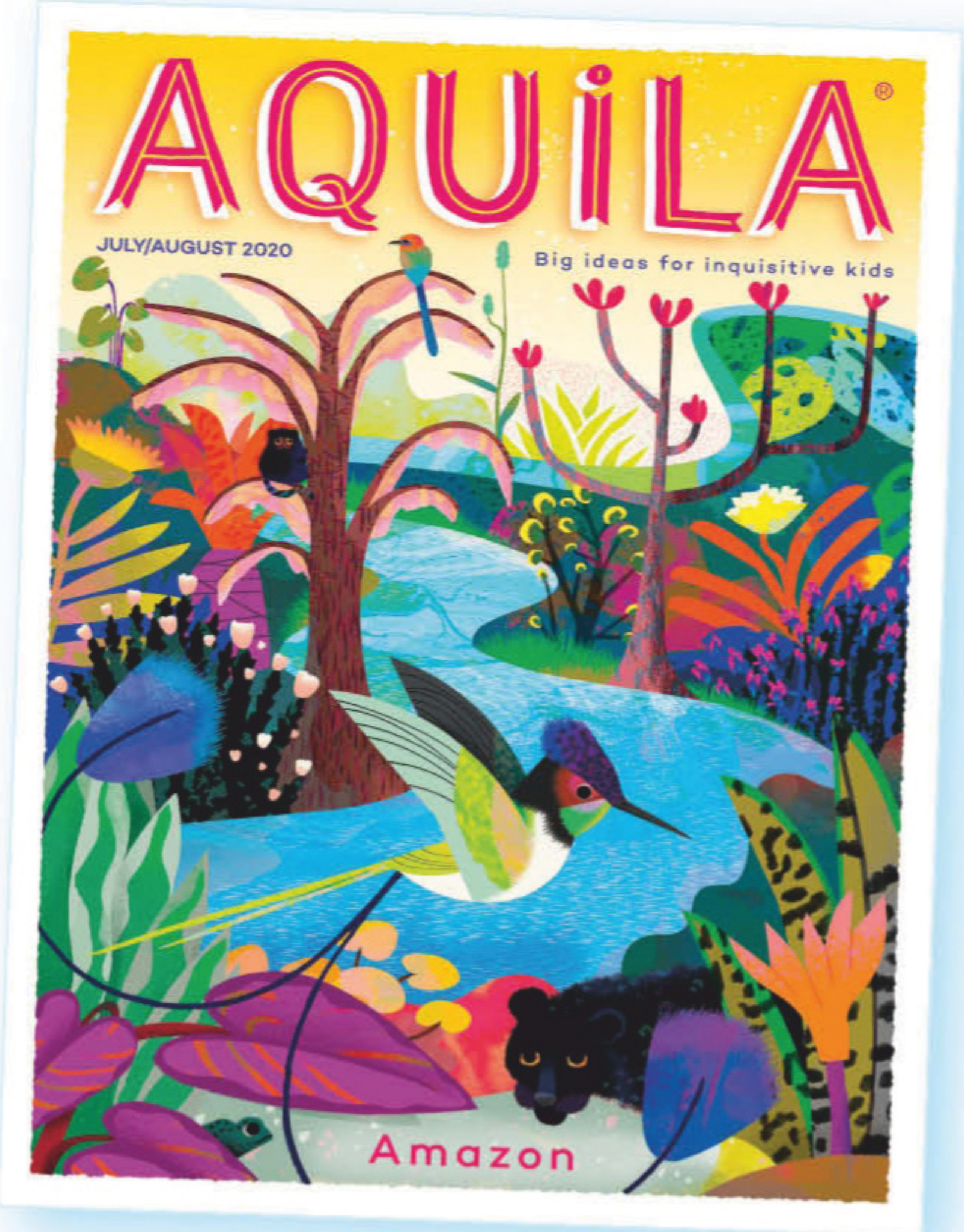

The Summer Double Issue takes children on an imaginative journey through the **Amazon Rainforest.** Discover remote **Indigenous Tribes** who hide from the Western world, plus meet **Pink Dolphins** and the well-travelled **Bear from darkest Peru** along the way!

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THE MYSTERY OF
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Editor's pick

How tough should we be on vaccine deniers?

Leader, 15 August

From Tim Stevenson, Prestwood, Buckinghamshire, UK

Your recent leader contemplates and quite reasonably rejects the idea of leaving those who refuse the offer of a hoped-for covid-19 vaccine to "their fate". An even harsher idea can be envisaged, although I don't for a moment advocate it. That would be to refuse healthcare to those who declined a vaccination without good cause and then contracted the disease.

However, some people might think a strictly utilitarian approach is appropriate. This would require the far from easy task of estimating the balance of two things. The first would be the lottery of punishment for many whose only offences were the inability to assess the evidence, gullibility in the face of foolish social media posts and the following of questionably motivated influencers.

On the other hand, the deterrent effect of such a draconian policy would need to be estimated, and thus its effect on increasing herd immunity and on the reduction of illness and deaths for those that the vaccine can't, for medical reasons, protect. Not easy. Not easy at all. But should someone attempt these sums?

This may mean life arose twice on Earth

8 August, p 34

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

I have often mused on the origins of viruses and their mention in "Life's big bang" has simply added to my confusion. The article says that viruses "can't have come first". So when did they arise, simultaneously or later?

If the latter, does this support the idea of some sort of second wave event in which a form of life separately emerged? And are such processes still occurring?

Let's scale up the plastic-eating beetle scenario

25 July, p 14

From Ben Haller, Ithaca, New York

It is very exciting to hear that there are beetle larvae that can, with the help of their gut bacteria, digest polystyrene waste. Wei-Min Wu at Stanford University in California notes that they probably couldn't chew through the whole lot, since each larva only consumes a few milligrams per day. Well, surely that depends on just how many beetles we bring to bear on the problem. Given that it might be good to start eating insect protein, there is an obvious synergy here.

However, an even better idea might be to cut out the middleman (middlebug?). If it is the bacteria that are doing the digesting, perhaps we could dispense with the beetles and let the bacteria loose on the polystyrene instead.

Sometimes weight gain is nothing to do with diet

25 July, p 16

From Jan Horton, West Launceston, Tasmania, Australia

Not all of us start equal in the "lose weight, get fit" stakes, as has been recommended to make us more resilient to the coronavirus. In my early 30s, with two young children, I regularly ran and competed in orienteering most weekends.

Then I had a medical emergency: a ruptured ovarian cyst. When I woke in hospital, the surgeon gently told me that as well as being unable to have any more children, I would also rapidly put on a lot of weight because of what they had needed to remove.

He was correct, despite me going on a strict diet as soon as I was released from hospital. Now, 40 years on, I remain pretty much at the weight at which I stabilised a year after surgery. It doesn't seem to matter what I eat (of a sensible diet) or how much I exercise.

So you can't assume being overweight is due to junk food, sugar, alcohol, fat or anything else.

Exactly who to label a troll may be tricky

1 August, p 21

From Larry Stoter, The North, Monmouthshire, UK

Annalee Newitz mentions that Meysam Alizadeh is working on a system that identifies social media trolls and forecasts what they will say next. It is an attractive concept and something that I would find useful, but I was puzzled by the focus on "foreign" trolls and influence campaigns. Surely there are plenty of trolls in the US itself, with one of the most prolific arguably being President Trump?

Nuclear critics must not be silenced

Letters, 15 August

From Philip Ward, Sheffield, South Yorkshire, UK

Environmental groups can't be sued by those who claim that they worsened climate change because they opposed nuclear plants, despite what Geoff Russell suggests. They don't decide to close plants or not to build them, governments do. The opponents of nuclear power must not be suppressed by legal fiat.

In around 70 years, nuclear power has grown so that it accounts for about 4 per cent of world energy use. To make a big impact on carbon emissions, perhaps 10 times as many reactors would be needed. Rapid building might see corners cut, so accidents must be expected, probably at no less a rate than has occurred so far.

There have been at least six significant nuclear accidents. With 10 times as many reactors, we could perhaps expect 10 times as many accidents – and 10 times the nuclear waste disposal problem that we already face.

A welcome bit of realism in the AI debate

4 July, p 46

From Robert Willis, Nanaimo, British Columbia, Canada

Toby Walsh's rebuttal to those who say AIs will usurp us, as seen in the extract taken from *Essential Guide: Artificial Intelligence*, is refreshing in both its objectivity and its specificity. As he notes: "Even if I can make my dog think faster, it is still unlikely to play chess."

Too many in the AI community seem to confuse their machines' speed for real thought. The fastest computation machinery possible doesn't incorporate intent or will, and probably never shall. Humans still have to determine what the machine will focus its abilities on and what "issue" requires attention and resolution. Walsh's arguments against fast AI equalling intelligence are spot on and it is time we stopped being misled by the speed-is-everything nostrum.

Testing will allow us to keep the world moving

Letters, 8 August

From Graham Jones, Bridgham, Norfolk, UK

The obvious solution to Linda Phillips's worries about the impact of extended border closures to combat the coronavirus is to test for it instead. Once we have a functional testing infrastructure in place, it should be possible to test everyone entering a country.

This will mean establishing facilities at every airport, seaport and the like. It should be possible to get results within hours, ideally minutes. Given the risk is highest when people are sharing the same aircraft, ship or whatever, it follows that there ought to be tests at the point of departure. ▮

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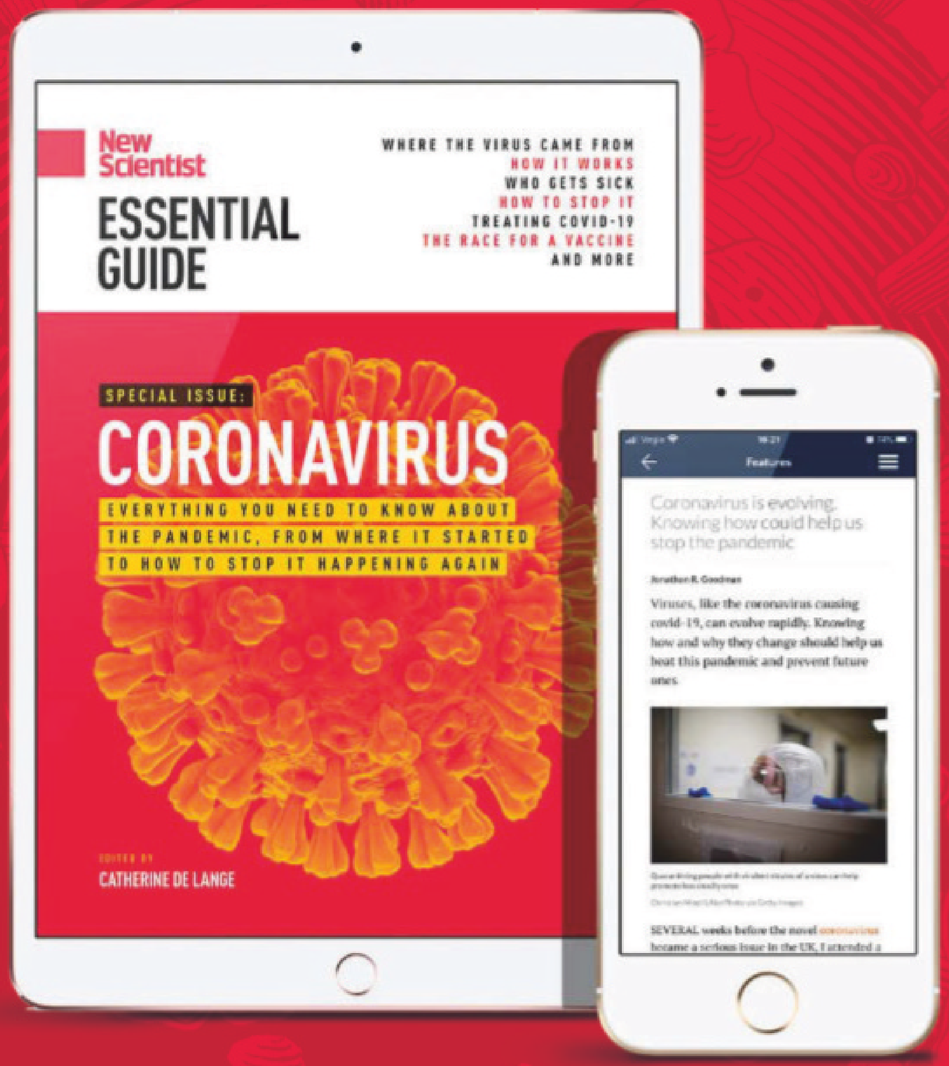

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SPECIAL ISSUE:
CORONAVIRUS
EVERYTHING YOU NEED TO KNOW ABOUT THE PANDEMIC, FROM WHERE IT STARTED TO HOW TO STOP IT HAPPENING AGAIN

EDITED BY
CATHERINE DE LANGE

Features

Coronavirus is evolving. Knowing how could help us stop the pandemic

Jonathan R. Goodman

Viruses, like the coronavirus causing covid-19, can evolve rapidly. Knowing how and why they change should help us beat this pandemic and prevent future ones.

SEVERAL weeks before the novel coronavirus became a serious issue in the UK, I attended a

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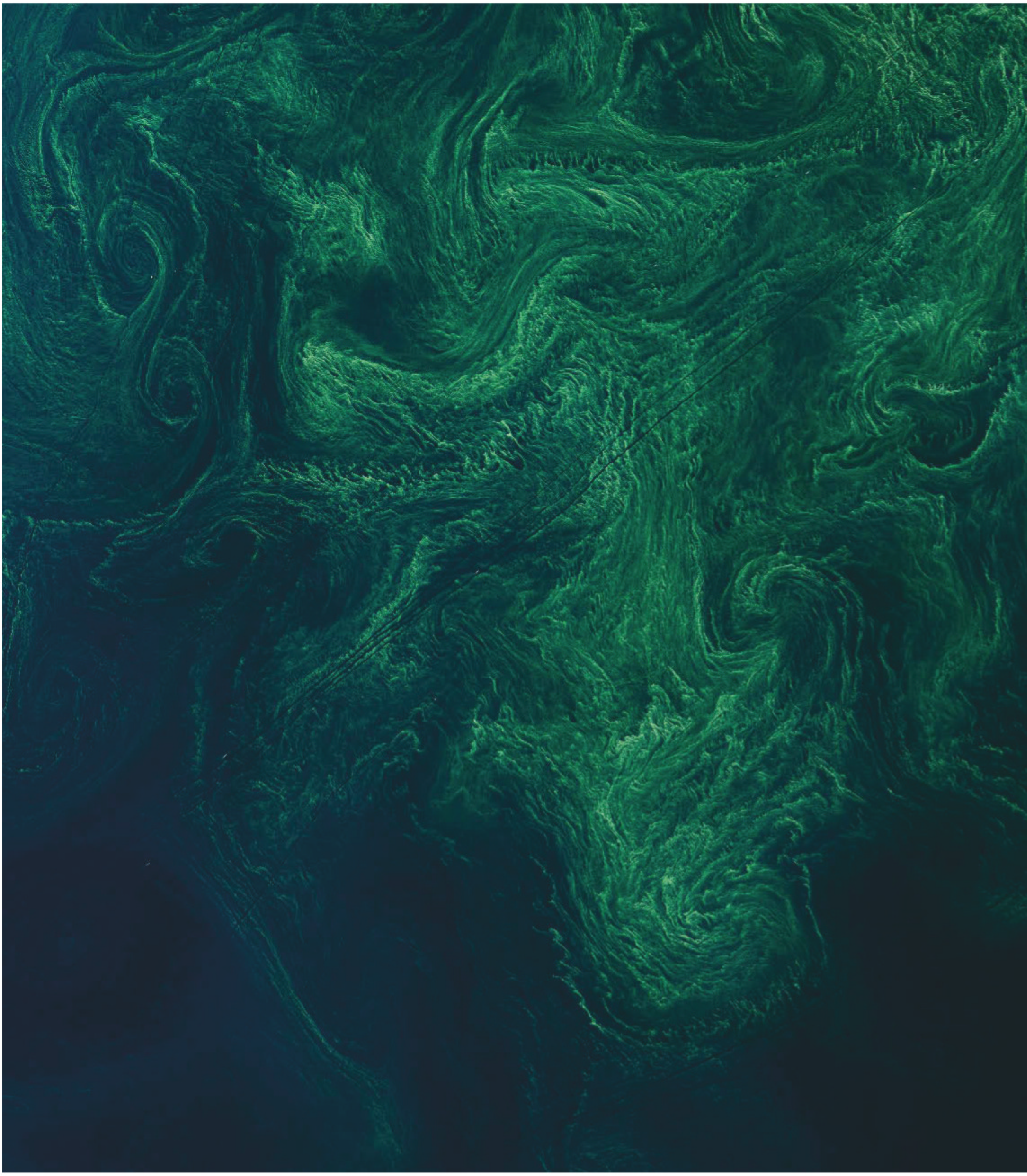
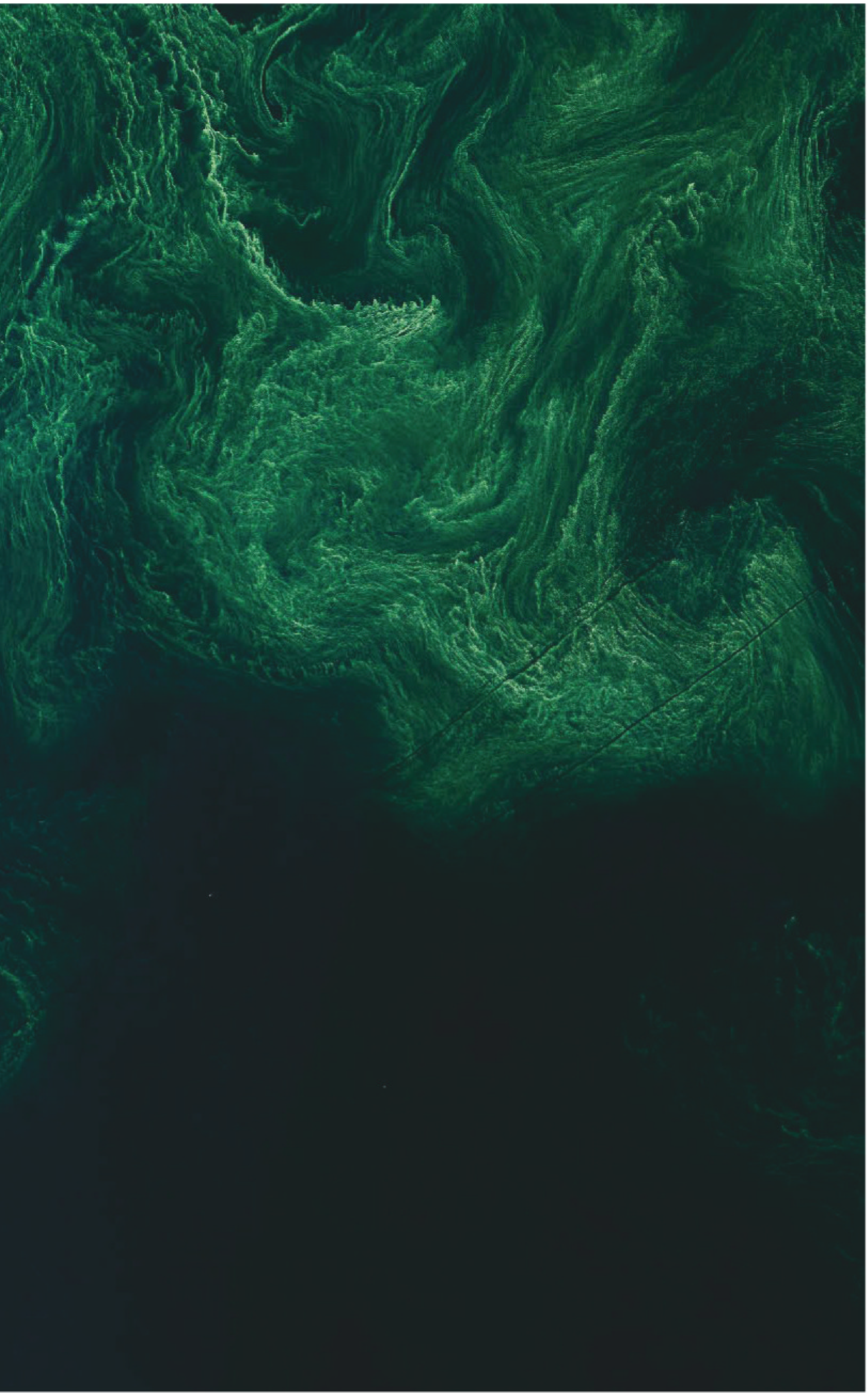




Baltic blooms

Image **NASA Earth Observatory/ Joshua Stevens**

MESMERISING swirls etch a fleeting pattern into the surface of the Baltic Sea that shifts with the currents. This colourful assembly, off the coast of south-east Sweden, is made up of high concentrations of phytoplankton. They are most likely to be cyanobacteria, which behave like plants and capture and store solar energy through photosynthesis.

Such phytoplankton blooms are more common in the summer, when plenty of sunlight is available at the water's surface. Blooms can span hundreds of square kilometres and last from a few days to several weeks, and no two are the same.

Phytoplankton fares particularly well in the Baltic Sea because the water contains plenty of phosphate, an essential nutrient for growth.

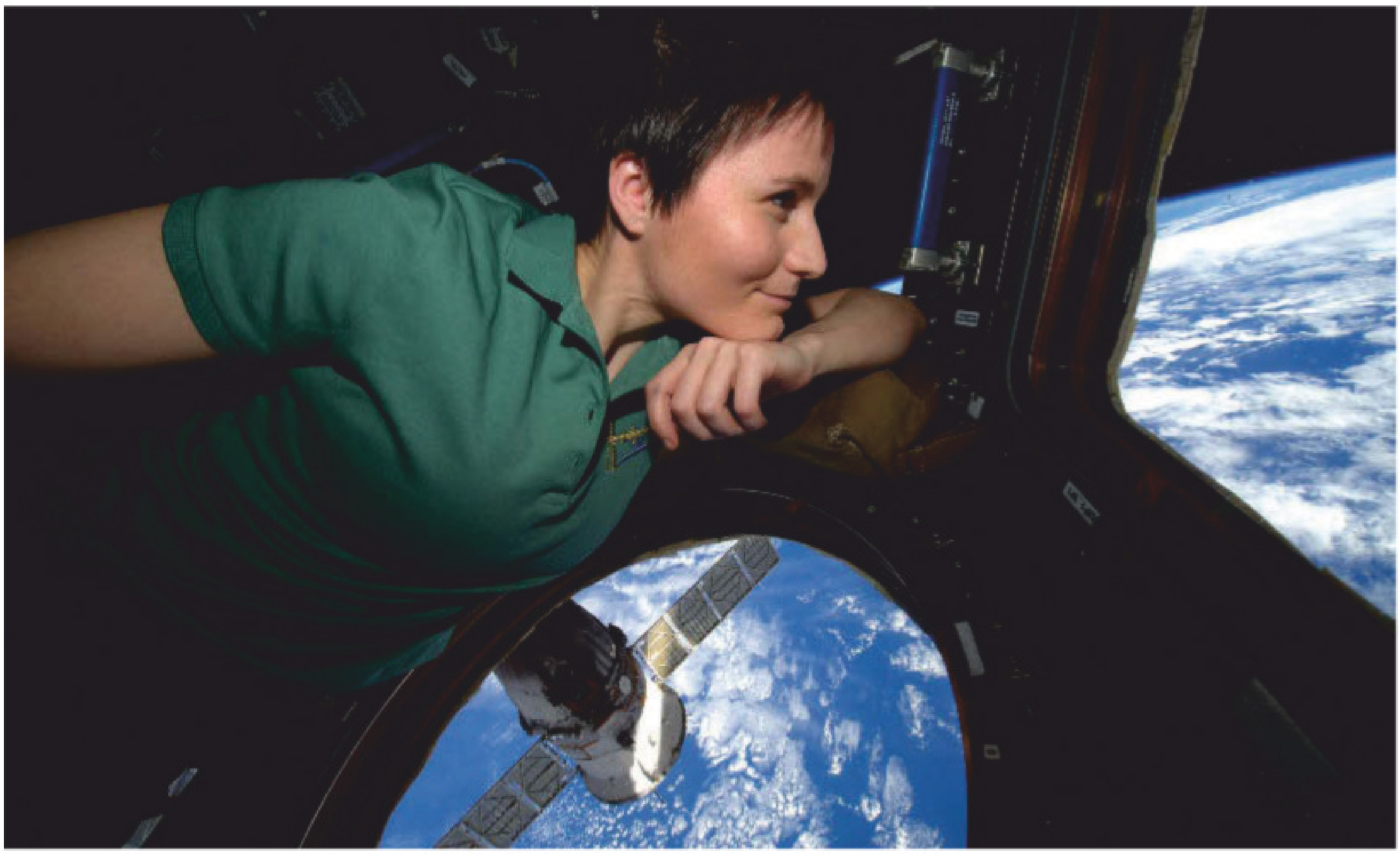
But blooms can signal trouble. If there are too many nutrients, often due to fertilisers or sewage leaking into water, phytoplankton can reproduce rapidly and the blooms explode in size. This can use up the water's oxygen, producing "dead zones" where very few organisms can survive.

This image was taken on 15 August by the Operational Land Imager, a remote sensing instrument that takes images of wide areas of Earth's landscape. It is onboard the Landsat 8 satellite that orbits Earth. NASA's Earth Observatory released the image last week.

Gege Li

Life as an astronaut

Who hasn't dreamed of exploring space? Books by two International Space Station crew members reveal the reality of astronaut life, says **David Silverberg**



ESA/NASA

Samantha Cristoforetti went from being a fighter pilot to an ISS astronaut

Books

Diary of an Apprentice Astronaut
Samantha Cristoforetti
Allen Lane

How to Astronaut: An insider's guide to leaving planet Earth
Terry Virts
Workman Publishing Company

FROM experiencing the sublime beauty of the blue planet through the porthole of a spacecraft to worrying about what happens if someone dies onboard, everyone wants to know what it is like to be an astronaut. It is, after all, quite literally like nothing on Earth.

New books by two fighter pilots who set out to discover how much of "the right stuff" they possessed don't disappoint. Fittingly, since Samantha Cristoforetti and Terry Virts spent 200 days together in 2014 aboard the International Space Station (ISS), their books are published just weeks apart.

Cristoforetti and Virts both chronicle their journeys from childhood dreams to the European Space Agency (ESA) and NASA respectively, but they capture their time off-world in different ways.

The diary-like approach taken by Cristoforetti is more obviously personal, with entries pegged to highlights such as the momentous phone call from ESA telling her she had been selected for astronaut training – which she missed after taking too long in the shower.

That was 18 May 2009, when she was a fighter pilot at Istrana Air Base in Italy, but her book begins six years later with an entry titled *TMA-15M, 11 June 2015*. At the end of her time in orbit 400 kilometres above Earth, she writes: "If everything goes to plan, we'll be reborn as Earthlings." She still holds the record for the longest uninterrupted spaceflight by a European astronaut.

There is even more poetry in Cristoforetti's account, as she describes the Mediterranean as looking as though Venus were about to emerge from the waters.

Virts takes a different tack. He first reached the ISS in 2010 and became an ISS commander in 2015. Each of his chapters covers a facet of astronaut life: in one, we learn that as a private cabin is the size of a phone booth, most astronauts clip their sleeping bags to the wall. Virts may seem less poetic than Cristoforetti, but he is the one who sometimes prefers to sleep floating, because it "feels like you are in a void, with nothing else in the universe other than your being; everything… fades to black".

> **"Burial 'at sea' means the crew must take the dead astronaut's body out of the airlock and push it into space"**

There is little about the onboard relationship between the writers in either book, but if you want a feel for them, there is an amusing video on YouTube in which Virts gives Cristoforetti a haircut.

The ISS is a serious place, however. Cristoforetti recounts the experiments in which she helped investigate the effects of space travel on the immune system and the microbiome. She also worked on a project to add nanoparticles to bone to combat osteoporosis – a vital issue in space as astronauts lose up to 10 per cent of their bone mass in months.

There are other big problems, too. Virts details what can happen if a crew member dies. Training allows for burial "at sea" or returning the body to Earth. If the person's family prefers the former, the crew has to take the body out of the airlock for a final spacewalk and push it into the void. It lacks the dignity of Spock's funeral in *Star Trek II: The Wrath of Khan*, but it is what could really happen.

So were there any dangers on the ISS? Virts recalls a seriously chilling moment when mission control told them there could be an ammonia leak on the station. In the end, it was a false alarm. Yet fear and thrilling spacewalks are the "icing on the cake", he says, adding that "usually with astronauts, our lives are all about the cake".

Each extraordinary second is earned by months of the kind of mundane detail that wouldn't even make the cutting room floor of that ultra-realist movie, *The Martian*. But perhaps that is the point: there is true wonder and poetry in such detail. ▮

David Silverberg is a writer based in Canada. He tweets @SilverbergDave

Getting real about climate

Ellie Goulding and David Attenborough help give a podcast fresh ways to bring the climate crisis centre stage, says **Anna Turns**

Podcast

So Hot Right Now

12 episodes, all podcast providers

THE way that we communicate the climate crisis needs a rethink, from the language used in daily conversations to the frequency it makes front page headlines.

The *So Hot Right Now* podcast goes to the heart of the issue. Far from detailing climate science, species extinctions or innovative technical fixes, the show questions the status quo and shares refreshing insight from experts, campaigners and front-line presenters.

"We tend to focus on gaps in our climate science knowledge and there's so much to learn, but what people are less alert to is this massive gap in coverage and that's hampering our chances of mainstreaming these topics. We need more airtime, more screen time for climate and nature," says co-host, journalist Lucy Siegle. "We're pushing the agenda, uncovering the barriers and exploring why the gatekeepers are not opening the gates, but also speaking to some of our heroes and asking them 'what should we do?'."

Siegle and wildlife film-maker Tom Mustill interview A-list guests such as Mary Robinson, former president of Ireland, UN climate negotiator Christiana Figueres and singer Ellie Goulding, who believes activism jeopardises her job. "I lose followers [on social media] every time I post about climate change. I lose at least a thousand followers," says Goulding during a podcast. She continues to speak up regardless.

In the first episode, David Attenborough says he has no idea why *Blue Planet II* sparked such an extreme public reaction to plastic pollution when he had been "plugging away" at the issue for years. "Suddenly, there was an unprecedented response, possibly down to the scheduling or the mood of the nation. Audiences are very hard to predict," he says.

Successful communication hinges on finding new avenues of storytelling that connect us to the natural world. As BBC *Springwatch* presenter Gillian Burke concludes in a later episode: "I'm really starting to play with the language, storytelling, identity and labels. If we're looking at the climate crisis through the lens of an Aboriginal person in Australia, how will that story be different? Language for me is a gateway to revealing more about the way we see the world."

Nuance exists in every word we use, suggests Siegle: "If language is too comfortable, it can minimise threat and the need for action, it can sometimes be downright dismissive or it can be too technical, forgetting that we respond to emotion, or it can be too emotional and not precise enough." Or, as Mustill adds, "it can be really boring. Part of the aim of communication is surely to entertain. No one wants to be a climate bore."

With a curious yet informal tone, some episodes last more than an hour and might work better as shorter, more finely tuned pieces. But there are no set rules and *So Hot Right Now* embraces the freedom to be experimental.

At times, the hosts seem starstruck (David Attenborough is thanked repeatedly for all he has done to inspire generations) but, generally, Siegle and Mustill enthusiastically arm listeners with a toolkit of useful strategies to articulate big ideas about climate and trigger more discussions.

Whether you are addressing world leaders about the environment, connecting with social media followers about the issue or arguing with relatives about it, *So Hot Right Now* is well worth a listen. ▮

Anna Turns is an environmental journalist based in Devon, UK

GRETA
THUNBERG

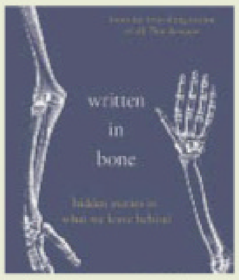
Hosts Lucy Siegle and Tom Mustill talk to influential guests on climate

ZOË LAW

Don't miss

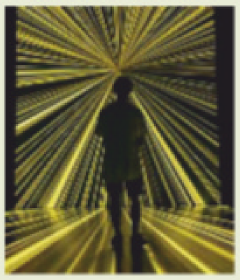
Watch

Away stars Hilary Swank as an astronaut leaving her husband and daughter to lead a mission to Mars. This Netflix sci-fi series is inspired by an article in *Esquire* about a mission of astronaut Scott Kelly.



Read

Written in Bone by forensic anthropologist Sue Black shows how the skeletons we leave behind us can be read for clues about virtually everything we eat and do, and everywhere we travel. Every bone has a tale to tell.



Visit

In Kepler's Gardens is Ars Electronica's bullish response to the covid-19 lockdown: a festival "measuring the new world" online and (where possible) in real life at 120 global locations, from Tokyo to Los Angeles.

NETFLIX, MYRIAM MÉNARD/ARS ELECTRONICA

The TV column

To boldly go and go

Star Trek, which began in 1966, is experiencing an extraordinary renaissance in the year 2020. Is this a golden age for the show, asks **Emily Wilson**

Emily Wilson is the editor of *New Scientist*. You can follow her on Twitter @emilyhwilson or email her at editor@newscientist.com

TV

Star Trek

Various

JAN THIJS/CBS

Michael Burnham (Sonequa Martin-Green) and Spock (Ethan Peck) in *Star Trek: Discovery*

THE very first episode of *Star Trek*, entitled The Man Trap, aired on 8 September 1966. Right from the start, all the key ingredients of *Star Trek* were there: an alien planet with air that was perfectly OK to breathe and strange lumps of rock on its surface that are good to hide behind in a firefight; very closely fitted colour-blocked uniforms; a key gang of ship's officers, including the captain, the Vulcan and the ship's doctor; and, of course, a really big spaceship, with that lift leading down from the bridge to the other decks.

There are a few things in that first show that have since disappeared, such as female crew members wearing skirts so short they barely covered their bottoms. But all the elements of *Star Trek*'s success were present in that story about an alien that killed people because it was badly short of salt.

What no one working on the show back then could possibly have imagined is that 54 years later, and in a very different world, *Star Trek* would not only still be in production, but that it would be thriving and, indeed, multiplying.

Whether or not this is a new golden age of *Star Trek* is for each fan to decide for themselves, but it is certainly an exciting period of renaissance.

My personal favourite of the crop of new series is *Star Trek: Discovery*, which kicked off in 2017. *Discovery* was the first new *Star Trek* TV series since *Star Trek: Enterprise* ended in 2005. It centres around science specialist Michael Burnham, played brilliantly by Sonequa Martin-Green. Burnham is largely sombre and angst-ridden, and yet you end up not only rooting for her but caring about her.

> **"*Star Trek: Lower Decks*, I'm informed by a US colleague, is 'being watched by all the cool people'"**

The rest of the show is rammed full of great ideas as well as other strong characters, including the fabulous Michelle Yeoh as Philippa Georgiou in a role that warps in very interesting ways as the show goes on. The second season came out late last year, and the third is due to be released this October, and if that happens, hurray!

Elsewhere in this renaissance is *Star Trek: Picard*, which was released in January, with Patrick Stewart reprising the role he played in *Star Trek: The Next Generation* (a hugely popular iteration of the franchise that ended in 1994). *Picard* is a slower show than *Discovery* and, in my view, is less successful as a piece of storytelling, but it isn't without its pleasures. A second and third season are on their way.

Then there is *Star Trek: Lower Decks*, an adult animated series that is only available to watch in North America right now. I am informed by a US colleague that it is "being watched by all the cool people".

These three are only one part of the new wave of *Star Trek,* though. So much more is coming, including, apparently, a live-action show based around Yeoh's rumbustious character in *Discovery* that is tentatively titled *Section 31*.

All these new shows harness the very best modern effects and all the narrative tricks learned from the masters of binge-watchable TV, and the *Star Trek* franchise has definitely come a long way since The Man Trap.

But the latest shows remain, indubitably, *Star Trek*. At their heart, there is still a bunch of people in tight uniforms, on a big spaceship, visiting alien worlds and taking with them *Star Trek*'s particular brand of tolerance and hope. What's not to like about that? ▮

Emily also recommends...

TV

Stargate SG-1

Brad Wright and Jonathan Glassner

The Stargate franchise has a central simplicity to it that is quite Star Trek: *humans going forth to strange new worlds to find and help others. It was kicked off by the 1994 film* Stargate *and now has a number of massive spin-off shows. For me, the 10 seasons of* SG-1 *are the main event. Aliens, jokes, great characters, pyramid ships, intergalactic narrative arcs – the show has everything.*

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**Leah
Crane**

Welcome to the fuzzy-verse

We expect the laws of nature that describe the universe to be exact, but what if that isn't true, wonders philosopher **Eddy Keming Chen**

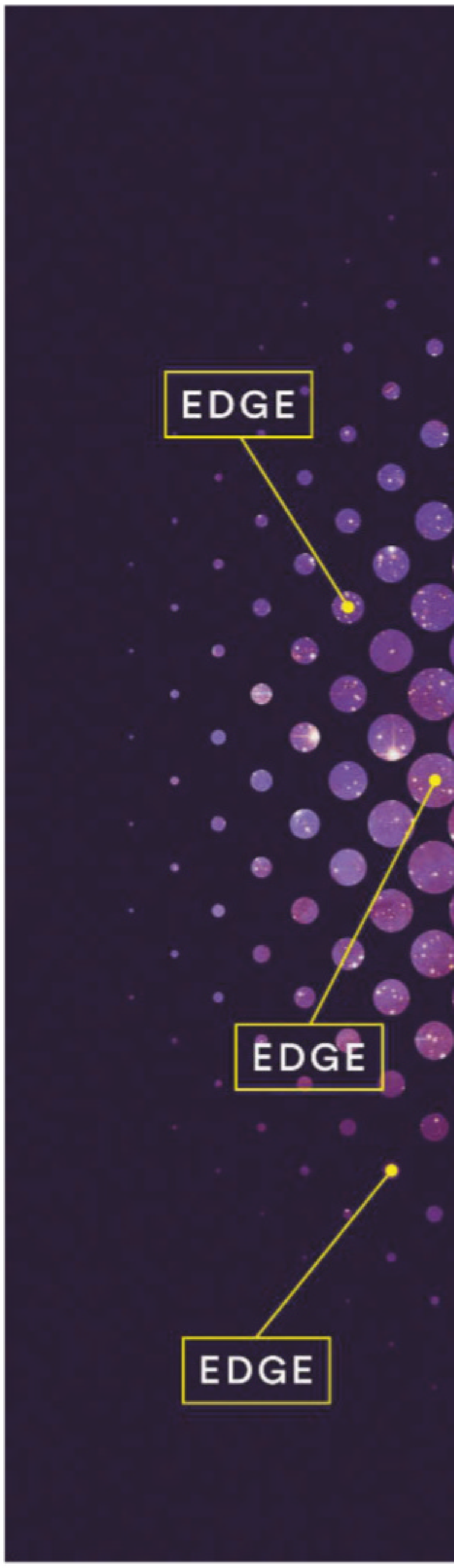
WHAT links a heap of sand, the edge of a cloud and actor Patrick Stewart's baldness? If you are only vaguely grasping what I am getting at, you are on the right track: they are all examples of imprecision in our description of the world. How many grains of sand can you take away from the heap and still call it a heap? Where exactly does the cloud end and the sky begin? How many hairs is Patrick Stewart allowed to have, and of what length, before he is classed as not bald? It is hard – perhaps impossible – to tell.

Such vague concepts, with their messy boundaries and borderline cases, are all around us. Until now, we have tended to assume they represent imperfections in our state of knowledge, our ways of communication or our modes of description. At some level, we think, the world must be precisely defined. Underpinning its workings, in the end, are the laws of physics, which are expressed using cast-iron mathematical equations that admit no vagueness.

I'm not so sure that's the case. I think I have uncovered a fundamental physical law that is itself vague. The implications could be far reaching, potentially casting doubt on the ability of conventional mathematics to provide us with a full description of the universe – but also perhaps opening entirely new avenues to even better physical theories.

Philosophers like me have spent a lot of time thinking about vague terms such as "bald" and "heap". The heap question is known as the sorites paradox, and it was noted as early as the 4th century BC. If a million grains make a heap, then a million minus one grains also make a heap, as do a million minus two grains and so on. Follow that logic, and eventually a single grain also makes a heap. That is absurd. So should we accept that there is a sharp boundary, some number of grains, below which grains don't make a heap? That is hard to swallow, too.

Vagueness is pervasive in natural language, and yet it resists logical analysis. The principle of bivalence that is central to



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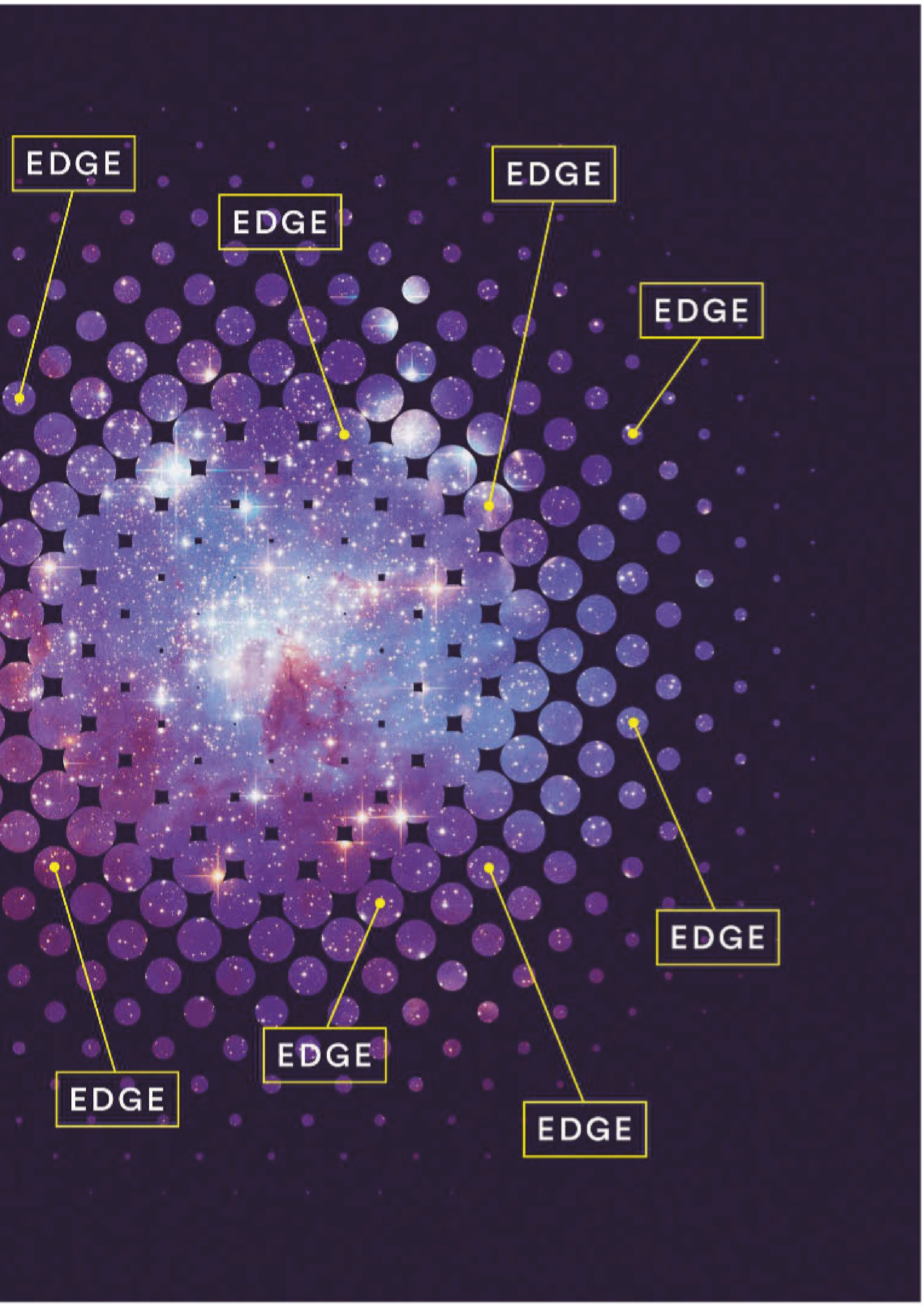


classical logic – every statement is either true or false – seems to fail for vague terms. Imagine Tom, who is a borderline case of "bald". It isn't true that Tom is bald. It isn't false that Tom is bald. Classical bivalent logic is at risk.

Philosophical reflections have identified three types of vagueness. First, there is semantic vagueness. This is just a feature of how we communicate. Perhaps some of the words we use really are so vague that they leave some statements in limbo, neither clearly true nor clearly false.

Second, it may be due to our ignorance of some facts. Even though it may not be clear how to draw a sharp boundary between bald and non-bald, or between heap and non-heap, there may be an objective cut-off that we aren't aware of. This we call epistemic vagueness, and it neatly preserves bivalent logic because there is a true or false answer to any statement, even if we don't know which it is.

Third, vagueness may be due to some genuine indeterminacy in the universe. This is called ontic vagueness. There are some objects we define using natural language, such as a cloud, or Mount Everest, that simply don't have exact boundaries in space or time.

While we can continue to debate what type of vagueness is at play in any one situation, one thing that unites most philosophers is that all of this has little to do with fundamental laws of nature. Vagueness may also appear in some high-level sciences, such as biology, where terms such as "cell", "organism" and "life" are imprecisely defined – a virus of the sort that is exercising us right now seems to be a classic borderline case of a living organism, as a bundle of genetic material that can only replicate inside the cells of another organism. But that vagueness should disappear when we drill down to more fundamental levels of explanation.

Fundamental laws of nature are written in the exact, non-messy language of mathematics. Mathematics, as we currently conceive it, is built around set theory, and a mathematical set is the very definition of being not vague. Something is either › a member of a set – the set of all odd numbers, say, or all numbers divisible by 11 – or it isn't. Sets are rigidly defined via a notion of equality: if two sets have the same members, they are the same set. Similarly, any mathematical function, topological space or geometrical shape built from sets is precisely defined. It is hard to see how the fundamental laws of physics could be completely and faithfully expressed in these terms if they admitted any vagueness.

On the margins

Take Isaac Newton's universal law of gravitation, for instance, or his second law of motion, force = mass × acceleration ($F = ma$). Physical laws such as these are arbitrary, in the sense that they are set by nature. From all the different ways the universe could be, these laws pick out a small subset of physically possible versions. They admit no borderline cases: the behaviour of objects within this reality will adhere to these equations exactly, no ifs, no buts.

These laws also have a quality that will become important later on: traceability. Our universe is sensitive to changes in the laws. Any shift in the gravitational constant, G, for example, will be felt by massive objects and will change, however slightly or significantly, the motion of planets around stars, the formation of galaxies, the distribution of matter in the cosmos or how a falling vase shatters when it hits the ground. G's exact value leaves a trace on the world. Similarly, if we change $F = ma$ to $F = ma^{1.001}$, it would produce observable physical changes: for a given force acting on a given mass, the resulting acceleration would be less.

The same arguments hold with all other fundamental equations of physics, for example Erwin Schrödinger's equation that defines the evolution of a quantum system, or Albert Einstein's field equations of general relativity that determine the development of the universe at large.

Did I say all? I meant not quite all. There seems to be one essential element of fundamental physics that has every

ALEXANDRA COOK/EYEEM/GETTY IMAGES

> **"The Past Hypothesis purports to be a fundamental law, and yet it is screamingly vague"**

Where does a cloud end and the sky begin? Vagueness might be an intrinsic property of how the universe works

right to be considered a law, but doesn't fit into this pattern.

Its origin lies in the puzzling observation that while the fundamental equations of physics are all time-symmetric, meaning they work equally well backwards as forwards, the world around us is distinctly time-asymmetric and irreversible. An arrow of time exists, a fact often encapsulated in the second law of thermodynamics, which puts limits on the sort of processes that can occur in reality. Ice cubes melt when placed in a drink to cool it, for example, but don't spontaneously form in it.

Explaining why leads to an influential proposal known as the Past Hypothesis. It says that the universe had a very special starting condition: it was initially in a state of low entropy, one with a high degree of order. This is about as fundamental a law about how the universe works as we have – and yet it is screamingly vague. In its weakest version, it simply says that the initial state of the universe has low entropy. How low is low?

I call this potential vagueness in a fundamental physical law "nomic vagueness". It seems distinct from the three other types of vagueness, and may be more basic. But let's take a closer look at what it consists of in the case of the Past Hypothesis.

First, its vagueness can be specified in a more precise way. We can characterise the initial state of the universe in terms of macroscopic variables such as temperature, volume, pressure and entropy, in accordance with astrophysical data. However, in classical statistical mechanics, this macrostate corresponds to any number of microstates of individual particles with different positions and velocities. Many different microstates look essentially the same to us as we measure the macrostate. Which microstates correspond to which macrostate is only vaguely defined. There are always going to be borderline cases where a particular configuration of particles might amount to an initial state of that particular temperature, say – or might not.

But what if we just stipulate the exact boundaries of the macrostate by saying the initial state of the universe corresponds to this set of possible microstates and no others? Let us call this the Strong Past Hypothesis. It means that any vagueness about the universe's initial state is due to our inexact knowledge of its macrostate. This is then similar to the epistemic vagueness we discussed earlier. So, nothing to see here?

Untraceable laws

The problem is that this Strong Past Hypothesis is arbitrary, and not just in the way other laws or constants are arbitrary. It is untraceably arbitrary: whereas changing the value of the gravitational constant makes a difference to what the universe is like, there are infinitely many ways of wiggling the boundary of the initial macrostate that make no difference to what the universe is like or even the probabilities of events within it.

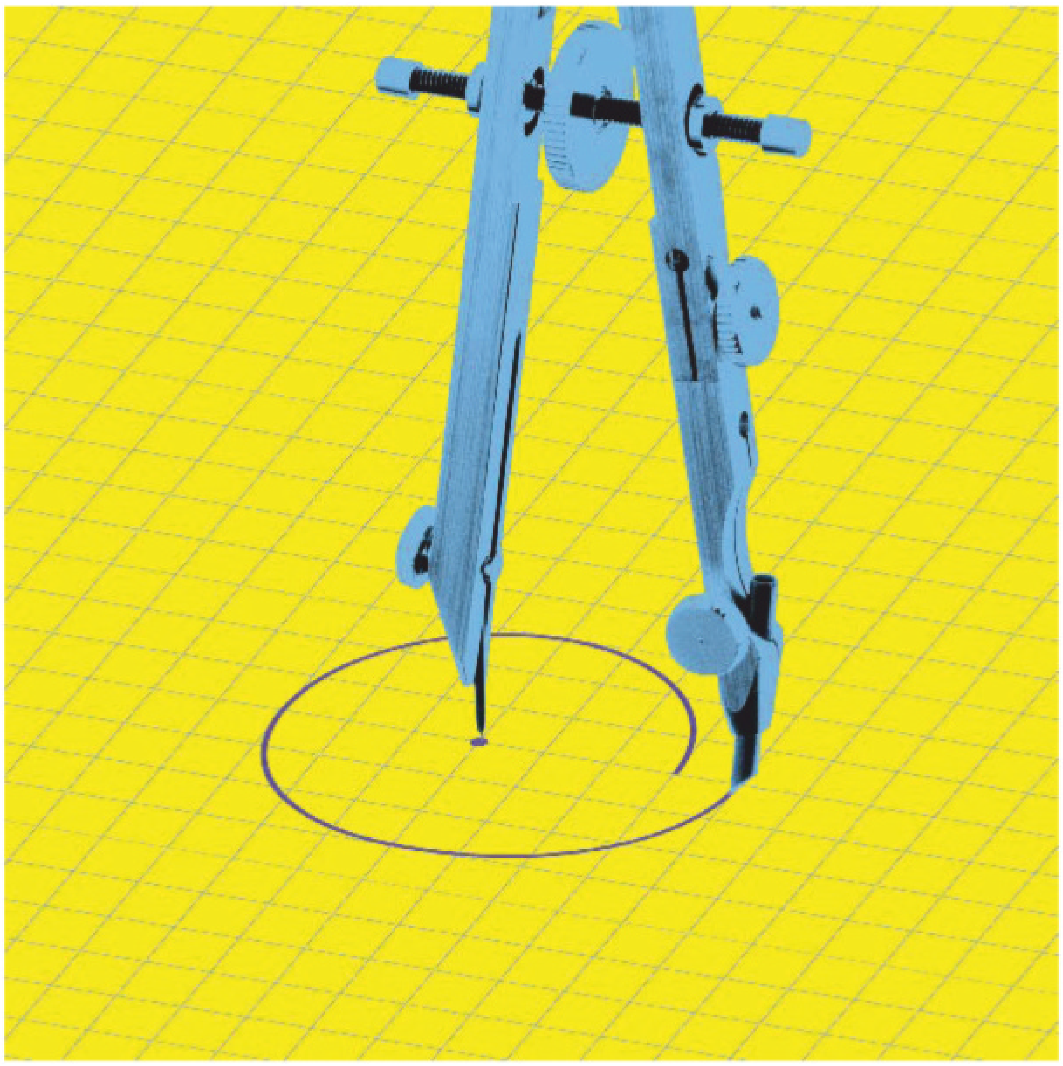
This leaves us on the horns of a dilemma: we either embrace nomic vagueness or nomic untraceability. That is to some extent a matter of taste, but I suggest we should avoid untraceability. Observations of the universe often can uncover the nature of traceable laws. By contrast, untraceable laws can't be pinned down by facts. We can't do science to determine what they are; there is a gap between untraceable laws and the world.

A resolution to this dilemma might still come from within physics, and from a rather surprising quarter – quantum theory.

At first glance, this would seem to be the last place to look to banish vagueness from physical laws. Quantum objects such as particles are described by "wave functions" that have no definite locations in space or other exactly defined properties. Besides reality thus apparently becoming riddled with ontic vagueness, the very process of measurement that resolves this vagueness, "collapsing" quantum wave functions into exact states, is itself painfully vaguely defined. In the words of physicist John Stewart Bell: "What exactly qualifies some physical systems to play the role of 'measurer'? Was the wave function of the world waiting to jump for thousands of millions of years until a single-celled living creature appeared? Or did it have to wait a little longer, for some better qualified system... with a PhD?"

Vagueness is indeed a feature of orthodox quantum theory – but other, competing interpretations are also available. In the many-worlds interpretation, when we probe a quantum system, the universe divides according to the possibilities we might see. There is no vagueness at the fundamental level in this depiction: the fundamental stuff is always exactly defined, and the dynamical laws are exactly specified. Meanwhile, in Bohmian mechanics, also known as pilot-wave theory, a single universe evolves deterministically at all times in accordance with exact mathematical equations. And in "spontaneous collapse" theories, wave-function collapse is just a random and spontaneous feature of the universe's dynamical laws, banishing any vague or mystical special role for the measurer.

How might this help with the Past Hypothesis? The details are complex, but it amounts to the fact that, unlike ›



MATT CHASE

classical mechanics, quantum mechanics allows us to connect the initial microstate and macrostate of the universe in an exact, traceable way. Traditionally, the initial quantum state of the universe is described by a wave function, and the Past Hypothesis restricts the possible wave functions to a small subset compatible with a low-entropy macrostate. Work I have done shows that we can specify the initial state of the universe as something equivalent to a sum over all these possible wave functions.

Fundamentally vague?

In pilot-wave theories and many-worlds theories, the form of the resulting "initial density matrix" will influence how things evolve subsequently; in spontaneous collapse theories, it will determine how collapses randomly happen. Changes to the initial density matrix will typically alter what the universe is like, just as is the case with other dynamical constants and laws. Thus quantum theory helps us to preserve both nomic exactness and traceability.

But there is no guarantee that such a solution is possible: we are far from achieving a quantum description of the beginning of the universe, and it may well be that a final theory of the nature of reality may not be fully quantum. If so, we again find ourselves on the horns of our dilemma, forced to admit nomic vagueness – and the consequences could be profound, not least for our ability to use mathematics to describe the universe. Any way of capturing a fundamental, yet vague, law such as the Past Hypothesis using traditional mathematics based on set theory will miss out something, or will impose too much sharpness somewhere.

This is perhaps an opportunity to think beyond classical mathematics for describing the universe. Other foundations besides set theory do exist for mathematics. Category theory, for example, focuses not on which mathematical objects are in which set, but on the abstract relationships between objects. Then there is homotopy type theory, which relaxes the notion of equality between objects central to set theory and defines objects in terms of paths between points in an abstract space. Either approach might provide a better language for capturing all physical laws, offering more flexibility in dealing with vagueness. Equally, it is possible that no mathematics can deal with it.

What about future laws of physics? That is a big unknown. But if nomic vagueness is possible, perhaps we don't have to restrict ourselves to formulating laws that can only be stated in precise mathematics. For example, the physicists Abhay Ashtekar and Brajesh Gupt have recently done some work on loop quantum gravity, one promising approach to unifying quantum theory with Einstein's theory of gravity, general relativity. Their proposal of an initial condition for the universe could be an instance of nomic vagueness, because of a vague boundary of the "Planck regime", the earliest epoch of the universe when the quantum effects of gravity dominated all other forces. It is one hint that a final theory of physics might not be entirely mathematically expressible.

Mathematics will still remain extremely useful. But if there is nomic vagueness, it may never completely capture the objective order of the universe. It may turn out that vagueness runs far deeper than defining the number of grains of sand in a heap or of the hairs on a bald man's head. ▮

"Mathematics may never completely capture the objective order of the universe"

Eddy Keming Chen is a philosopher of physics at the University of California, San Diego, and a fellow of the John Bell Institute for the Foundations of Physics

SHUTTERSTOCK/SASIN PARAKSA

Moonstruck

The idea that lunar cycles influence our health has long been dismissed as unscientific. Is it time to reconsider, asks **Jo Marchant**

IN FEBRUARY 1954, biologist Frank Brown discovered something that made no sense. While investigating whether oysters can keep time, he had found that they open their shells to feed at high tide, roughly twice a day. Brown had a hunch they weren't simply responding to changes in their environment but would continue the rhythm even if moved far from the sea. To find out, he shipped a batch of oysters from the ocean off New Haven, Connecticut, hundreds of kilometres inland to Northwestern University in Evanston, Illinois.

Brown kept the shellfish in a sealed darkroom, shielded from changes in temperature, pressure, water currents and light. At first, the oysters kept their rhythm, feeding each day in time with the New Haven tides. Then, something strange happened – their feeding times gradually shifted until they lagged 3 hours behind. Brown was mystified, until he realised that they had adapted to the local state of the moon: they were feeding at times when Evanston, if it were by the sea, would experience high tide. Despite having no obvious environmental cues, it seemed these shellfish were somehow tracking lunar cycles.

Brown became convinced that oysters, humans and all life forms are plugged into subtle cosmic cues, continuously sensing both lunar and solar movements to coordinate biological processes, from metabolism to reproduction. But his ideas seemed outlandish to his peers. Brown's results were forgotten, and the notion of lunar influences was dismissed as pseudoscience. Now, growing evidence from a range of fields suggests he might have been right. Perhaps, hidden beneath

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"Evidence is growing that the influence of the moon is more widespread than we thought"

our more obvious earthly rhythms, we are also creatures of the moon.

The belief that the moon guides life on Earth goes back millennia. The ancient Greeks thought female fertility had a lunar source, noting that the menstrual cycle averages 29.5 days, the same as the period between consecutive full moons. The word "menstruation" is derived from the Greek *mene*, meaning moon. The moon has also traditionally been believed to influence mental health, hence the pejorative term "lunatic" (from the Latin *luna*, or moon).

When the foundations for the modern field of chronobiology were laid in the 1950s and 60s, however, most researchers focused on daily rhythms. These appeared to be driven by internal, biochemical timers nudged by physical cues, especially sunlight.

Shadow of the sun

A key line of evidence came from a bunker built into a Bavarian hillside by German physiologist Jürgen Aschoff. Starting in 1964, hundreds of volunteers lived alone in the bunker for months at a time, shielded from sunlight and any clues to the time of day. It had already been established that our sleep-wake rhythms, as well as aspects of our physiology ranging from body temperature to metabolite excretion, vary with the 24-hour day. In the bunker, these cycles persisted, but they lagged a bit slower than normal. Aschoff concluded that Brown was wrong: our daily rhythms don't respond to unidentified cosmic signals, otherwise they would presumably still keep perfect time. Although usually entrained by the sun and other environmental cues, our internal clocks can carry on running independently.

Chronobiology became hugely successful. Since the 1980s, we have identified multiple genes that encode proteins that regulate each other in a complex network of feedback loops. This creates a steady cycle that pulses once each day in time with the sun. Such circadian clocks are now recognised as a defining feature of life: they tell animals when to feed, run, sleep and digest, help plants ration their starch reserves through the night and signal thousands of ocean plankton species to avoid predators by sinking before dawn and rising each evening in the largest movement of biomass on the planet.

By tracking shifting times of sunrise and sunset, these clocks drive seasonal changes too, telling creatures when to migrate, moult and reproduce. In medicine, the implications of living out of sync with the solar day are now known to include insomnia, depression, obesity, heart disease and cancer.

Lunar influences, on the other hand, have received less attention, in part due to their colourful folk history. As chronobiology took off as a serious field of study, mentions of the moon were discredited or ignored, and researchers have conventionally investigated solar effects in isolation, as if the moon didn't exist. Now, evidence is growing that the impact of the moon is more widespread than previously thought. We have long known that its pull on our planet causes the oceans to bulge out, leading to high and low tides in coastal areas, but how the moon influences life in the seas is also becoming clearer.

Aquatic species that reproduce by releasing eggs and sperm into the water often use lunar phases to help time their spawning to a tight window. On Australia's Great Barrier Reef, hundreds of millions of corals release so many eggs and sperm in moon-driven mass events that they turn the ocean pink. Meanwhile, many tidal creatures depend on extra-large spring tides that happen twice each month when Earth, the moon and sun are aligned in a way that creates extra gravitational pull. Marine midges, which live in algal mats off rocky Atlantic shores, emerge as adult flies only when the seabed is exposed at the lowest low tide. Japanese land crabs anticipate high tides, climbing down from the mountains where they live to release their offspring into the sea.

Many inland animals also rely on the light of the moon to reproduce and survive. Predators including owls, wolves and snakes hunt by moonlight. North American birds called whip-poor-wills hatch during the new

NASA GODDARD

moon so the chicks' highest energy demand comes two weeks later, when there is moonlight to help their parents catch insects. Serengeti wildebeest use the moon to time conception so calves are born safely ahead of the species' spring migration. And in 2015, biologists reported the first example of lunar reproduction in a plant. *Ephedra foeminea*, a relative of conifers and cycads, attracts insects during the full moon by exuding drops of sugary liquid that glitter like diamonds in the moonlight.

These effects can shape entire ecosystems. In 2016, biologists reported that in the Arctic Ocean during midwinter, when the sun doesn't rise, the mass daily sinking of oceanic plankton switches to a 24.8-hour cycle, following the moon.

The mechanisms behind such behaviour have remained elusive. Are organisms passively responding to environmental changes, or are they driven by internal lunar clocks? Over the past few years, genetic studies have shown that lunar cycles directly regulate biology in marine species such as coral, bristle worm and rabbitfish. A 2017 study of *Acropora gemmifera* coral from Taiwan found that the activity of hundreds of genes varied with lunar phases, including ones involved in key functions such as cell signalling and cell division. What's more, several studies have now shown that these cycles continue in constant laboratory conditions.

Another surprising discovery was that many of the genes that vary with lunar phases are involved in the circadian clock. A 2019 study found that when oysters were kept in constant conditions, several genes thought of as core components of the circadian clock instead ran with a circatidal frequency, to match the tides.

"That would suggest that a part of the circadian clock can do a tidal oscillation as well," says Kristin Tessmar-Raible, who studies molecular mechanisms of lunar cycles at the University of Vienna, Austria. The clock machinery in these marine species is more complex and thought to be evolutionarily more ancient than that of mice, humans or fruit flies. She says it suggests that, at least for short cycles on the scale of hours, life's ancestral clock could actually be tuned to the sun and the moon.

This new evidence highlights the problem of considering solar and lunar effects in isolation. "I think this is wrong," says Tessmar-Raible. The approach can be useful for unravelling molecular mechanisms in the lab, she argues, but doesn't make sense from an ecological point of view. "Nature is a combination of sun and moon."

The idea that there are lunar effects on our own body clocks has been particularly contentious. Studies attempting to link events such as violent behaviour, the menstrual cycle or births to lunar phases have yielded mixed results, with rigorous, recent studies often finding no effect.

ERIK JOHANSSON

The moon has fascinated humans for centuries, but only recently have we begun to understand its influence on living things

NASA GODDARD

Some have argued that there is no point even doing further research; the very idea of such influences was described in a recent review as "paranormal".

But Tessmar-Raible points out that because genetically controlled lunar rhythms have now been found across the animal kingdom, from fish to invertebrates, it wouldn't be surprising if they exist in some form in humans too. Michael Smolensky, a chronobiologist at the University of Texas at Austin, agrees. Lunar effects may have disappeared in more recent studies because we are no longer exposed to natural patterns of moonlight, he says. "Humans have been separated from their environment."

There is plenty of research keeping the debate open. A 2019 study of more than 2600 suicides in northern Finland found that the rate increased at full moon, but only in premenopausal women. The researchers suggested that this could be caused by lunar effects on the menstrual cycle, as its hormonal changes correlate with feelings of depression.

German researchers reported to the European Biological Rhythms Society last year that moonlight can set the rhythm of menstrual cycles. Several recent studies have also found that sleep quality varies with the phase of the moon – with shorter, poorer sleep at new moon – even in constant lab conditions, although others haven't seen this effect. Disrupted sleep, in turn, can trigger seizures and exacerbate conditions such as bipolar disorder and schizophrenia.

Perhaps most intriguing of all is a 2018 study by Thomas Wehr, a psychiatrist and sleep researcher at the US National Institute of Mental Health. He studied people with bipolar disorder who tracked their sleep times and mood over several years, and concluded that switches between high and low mood were triggered by varying sleep patterns linked to lunar cycles. One of the patients, who recorded his sleep times for 17 years, went to sleep at the same time each day but his waking time was on a 24.8-hour cycle, with the moon. That meant sometimes he got hardly any sleep, and other times he slept most of the day. Wehr suggests his waking time had become erroneously linked with the lunar day.

Philip Lewis, who studies circadian biology at the University of Cologne, Germany, describes Wehr's work as "absolutely fascinating". Back in Aschoff's bunker in the 1960s, when volunteers were shielded from the sun, the timing of their daily cycles slipped, a result that helped to kill off Brown's idea of cosmic cues. But the average shift was to a 24.8-hour period – the length of the lunar day, Lewis points out. What if, in the absence of solar cues, these human subjects were somehow following the moon? The timing is "suspicious", agrees Tessmar-Raible, though she emphasises there is no direct evidence as yet that this effect is caused by the moon.

> **"Genetically controlled lunar rhythms have been found across the animal kingdom"**

Crucially, the effects seen in Wehr's study don't match up with lunar phases, so couldn't have been caused by varying levels of moonlight. Instead, the people's sleep seemed to be influenced by tidal cycles – but by what mechanism might the people studied by Aschoff and Wehr sense lunar movements?

One speculative suggestion is gravity. There are studies hinting that subtle gravitational changes can influence growth in plants, for example. Another possibility was first suggested by Brown. Back in the 1950s, he wanted to know how his oysters were tracking the moon. He filled mazes with thousands of more mobile invertebrates –mud snails and flatworms – and found that they oriented according to very weak magnetic fields, with a preferred magnetic direction that changed according to the lunar phase. The movements of the sun and moon create subtle ripples in Earth's magnetic field; Brown suggested that an ability to sense these changes explained his mysterious results.

After that, Brown was dismissed even more harshly. Earth's magnetic field is extremely weak, about 200 times weaker than a fridge magnet, and the lunar ripples are even tinier. There was no known mechanism by which such small changes could influence biological processes. Yet even though many shunned his work in public, they didn't ignore it completely. Aschoff, working with a physicist called Rütger Wever, actually built two bunkers. They were identical except for one thing: one was shielded from Earth's magnetic field. If the volunteers' daily rhythms continued to run regardless, it would prove Brown wrong, or so the idea went. They did indeed continue, clinching the notion of an internal clock, but the results from the two bunkers weren't the same.

In the shielded bunker, the subjects' rhythms slipped even further behind and became more variable. Sometimes, different body clocks became uncoupled. In the 1970s, Wever published the results in a series of now-obscure papers. He described the effects as "remarkable", the first evidence that humans are influenced by Earth's magnetic field. But Aschoff didn't mention the shielded bunker in his own high-profile studies, and chronobiology research continued as if the experiment never happened.

Biologists studying navigation, however, have since realised that animals can sense vanishingly weak magnetic fields through a variety of methods. Fish use networks of jelly-filled canals to measure the flow of current as they swim through a field. Some bacteria use tiny magnetic crystals to steer themselves along field lines, and similar crystals are found in lots of species, including humans. Another mechanism appears to involve light-sensing molecules called cryptochromes. Light pushes the molecule into an activated state, and sometimes even a tiny nudge from a magnetic field can influence the rate at which this occurs.

Cryptochromes have a wide range of functions, from regulating growth rate and flowering in plants to enabling magnetic navigation in birds and butterflies. Intriguingly, they are also involved in biological clocks. Neuroscientist Steven Reppert at the University of Massachusetts says that in monarch butterflies, magnetosensing for navigation seems to occur independently of a biological clock. However, magnetic fields have been shown to alter the period length of the circadian clock in several insect species including cockroaches.

There are now even hints that humans are sensitive to magnetic fields after all. In 2011, Reppert inserted a human cryptochrome into fruit flies whose own cryptochrome had been disabled and found that it restored their ability to navigate using magnetic fields. So it is possible that cryptochromes function as magnetosensors in humans, he says, "but more work is needed". Meanwhile, Joseph Kirschvink at the California Institute of Technology, who believes that magnetite crystals play this role instead of cryptochromes, reported last year that electrical activity in volunteers' brains responded to changes in the magnetic field.

Perhaps alongside the more obvious cues such as light and temperature, subtle magnetic ripples really are keeping our bodies and brains in constant touch with the movements of the moon and sun. "Probably most people would laugh about it, but I would not keep it out of the equation," says Tessmar-Raible. "It's definitely something we should look into if we want to understand this." A first step, she suggests, might be to test whether the lunar cycle in model species such as bristle worms or marine midges can be shifted using magnetic cues.

Half a century ago, Brown described living creatures, including humans, as an inseparable part of an electromagnetic cosmos. Organisms and their environment, he said, "merge intimately for timing of life". His vision was discarded in favour of autonomous, biochemical clocks, tuned by sunlight. Yet for all the success of that model, maybe Brown, too, was onto something. "Animals use all available timing cues and this includes the moon equal to the sun," says Tessmar-Raible. "Now, the more people look, the more they find." ∎

This travelling exhibit brought the moon down to Earth, but our satellite may affect us from afar too

AIMEE MCARDLE/TRUSTEES OF THE NATURAL HISTORY MUSEUM LONDON

Jo Marchant is a science journalist based in London. Her new book *The Human Cosmos* is out this month

How WEIRD are you?

Most psychological research involves people from rich, democratic countries. We are missing the bigger picture of human thinking, **Joe Henrich** tells Dan Jones

ROCIO MONTOYA

HOW does the culture we live in influence our psychology, motivation and decision making? Joe Henrich was a cultural anthropologist working in the Amazon when he first tried to find out. He pioneered the use of experimental cooperation games like the prisoner's dilemma and the ultimatum game outside the lab. Later, he realised that his findings have big implications for psychological research, which tends to focus on students from Western backgrounds. In 2010, he introduced the "WEIRD" concept to describe the unusual psychology of the subjects in the vast majority of these studies. Now professor of human evolutionary biology at Harvard University, he tells *New Scientist* about the origins of WEIRDness, its impact on history and its role in the modern world.

Dan Jones: When did you realise that you, your colleagues and most of the people you teach are WEIRD?

Joe Henrich: The WEIRD label emerged from a series of lunches I started having around 2006 with two cultural psychologists, Steven Heine and Ara Norenzayan. We had noticed that in the behavioural sciences and psychology in particular, about 96 per cent of study participants were from Western, Educated, Industrialised, Rich and Democratic societies – and that they were often psychological outliers in comparison with other populations. WEIRD people tend to show greater trust in strangers and fairness towards anonymous others; think more analytically rather than holistically; make more use of intentions in moral judgements; are more concerned with personality, the self and the cultivation of personal attributes; they are more individualistic and less loyal to their group; and they are more likely to judge the behaviour of others as reflecting some enduring disposition rather than temporary situational factors.

So is it the West versus the rest?

It is important not to set up a dichotomy between the WEIRD and non-WEIRD. WEIRDness is a multi-dimensional continuum, and there is a lot of variation even within Western Europe. In a recent paper, we took data from the World Values Survey and, using techniques from population genetics, analysed the cultural distance of various populations from the US, the weirdest of WEIRD countries. This WEIRD scale shows New Englanders as the WEIRDest population in the world and substantially different to populations in the Middle East and Africa at the other end. Interestingly, although there is a huge body of research in social psychology setting up an East-West dichotomy, it turns out that the typical subjects studied in Japan or China are kind of in the middle of the WEIRD spectrum.

How did the WEIRD mind evolve?

This is the question I have been trying to answer for the past 10 years. In my new book, *The WEIRDest People in the World: How the West became psychologically peculiar and particularly prosperous*, I argue that social changes ushered in by what I call the

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marriage and family programme of the Western Catholic church was a major driving force, especially their impact on kinship.

Why is kinship so important?
Kinship systems are collections of norms that define how we should behave in various contexts. They were likely the first human social institutions to emerge because they are built on our evolved psychology. The institution of marriage, for example, taps into our species' pair-bonding psychology, and notions of extended kin groups play on a core kinship psychology for helping and caring for our children, siblings and other close relatives.

The social norms that make up kinship systems structure the world you are born into. They shape who you can marry, what you can inherit and own, who you form alliances with, where you live and what kind of economic activities you engage in. As we grow up among the norms and institutions of our society, we develop psychological adaptations to navigate this social world.

What does kinship have to do with WEIRDness?
In most agricultural societies, people have lived enmeshed in kin-based institutions within tribal groups or networks. Inheritance and post-marital residence often followed either the male or female line – but not both – so people often lived in extended unilineal households, and wives or husbands moved to live with their spouses' kinfolk. Many kinship units collectively owned or controlled territory, and kin-based organisations provided members with protection, insurance and security, caring for sick, injured and poor members as well as the elderly. Arranged marriages with relatives such as cousins were customary, and polygynous marriages were common for high-status men. These intensive kin networks nurture a non-WEIRD psychology, creating a more collectivist mindset with greater conformity, obedience to authority, nepotism and in-group loyalty.

How did the church change kinship systems?
The Western church introduced prohibitions on marriage to blood relatives that were extended to include distant relatives, eventually up to sixth cousins, which broke down ties between families, tribes and clans. It prohibited polygamous marriage and discouraged the adoption of children so that some lineages simply died out because they had no heirs. The church also encouraged, and sometimes required, newly married couples to set up independent households, and promoted the individual ownership of property.

Why would this change people's psychology?
Instead of being born into a world where you inherit most of your social relationships, where everything is about social relationships, and there is strong in-group loyalty, obedience and conformity, now you have to find and develop your own mutually beneficial relationships. And when you are deciding which towns, guilds or other voluntary associations to join – which will be your new safety net, rather than your kin network – you are looking for people that share your interests, beliefs and so on. This focuses attention on people's underlying personalities, traits and dispositions, rather than their pre-existing relationship to you. Your success in the world is now tied to cultivating your attributes, making yourself appealing to others because you are going to do business together or get married.

> "The picture of psychology we have doesn't represent that of *Homo sapiens*"

How have you gone about testing this idea?
First we created two "kinship intensity" indices. One measured the strength of kinship ties in more than 1200 populations from around the world, drawing on anthropological observations dating back more than 100 years and recorded in the Ethnographic Atlas [a database of cultures across the world]. The other looked at rates of cousin marriage across Europe over the 20th century, with higher rates meaning higher kinship intensity. We also developed measures of how long different countries and regions within Europe had been exposed to the Western church. Then we looked at 24 psychological variables related to WEIRD psychology that have been studied across many countries and populations. We found that the weaker the historical measures of kinship intensity and the longer the church had been present, the WEIRDer the minds of people living there today.

You believe WEIRDness also helps explain how the West became "particularly prosperous". What is the link?
A WEIRDer and more individualistic psychology provides fertile ground for the development of formal institutions and notions of individual rights and equality before the law that would be hard to conceive of in a world of clans or kindreds. As people

VISIONS FROM EARTH/ALAMY

In traditional Fijian communities, you are born into an extended kinship network that shapes your mindset in many ways

in the West moved away from tight kinship networks towards voluntary associations of strangers in the form of labour unions, guilds, monasteries, universities and businesses, they adjusted psychologically to be more trusting of people outside their kin group and also developed contract law to buttress voluntary associations. This happened much earlier than in places such as China. The WEIRD mind is also particularly patient, as documented in many studies, which – combined with trust and an individualistic drive to set yourself apart – helps drive innovation in technology and economic activities. This eventually launched the Industrial Revolution.

What are the downsides to WEIRDness?

In societies where there is a strong sense of kinship, like Fiji where I have done fieldwork, there is a sense of security, community, oneness – a kind of comfort that comes from the warm embrace of knowing you are at the centre of a tight web of relations who will always have your back. They aren't tied to you because you are a convenient contact or are currently smart or successful, they are tied to you in a deep way and they will be tied to your children. This is a snug, secure, happy feeling. WEIRDness undermines this feeling.

People living in tribal or clan-based societies also tend to see themselves as links in a chain connecting past to future, creating a sense of continuity that gives people a real sense of meaning and security. Then you get Westerners who are like "I'm an individual ape on a pale blue dot in the middle of a giant black space" and "What does it all mean?".

What are the consequences of psychology's bias towards WEIRD subjects?

It means that the picture of "human psychology" portrayed in the textbooks, and still in many journal articles, doesn't represent the psychology of *Homo sapiens* at all. Perhaps even more concerning is how this bias hampers our efforts to understand the origins and nature of psychological processes and brain development. Much of what looks like reliably developing features of minds, with clear developmental trajectories over childhood, turn out to be the result of cultural products, like the institutions, values, technologies or languages individuals confront and must learn, internalise and navigate to make their way in the world. This applies not only to psychology and neuroscience – including perception, memory, learning, motivations, reasoning and sociality – but also to aspects of human physiology, anatomy and health. WEIRD people have flat feet, impoverished microbiomes, high rates of myopia and unnaturally low levels of exposure to parasites like helminths, which may increase their risk of heart disease and allergies.

Then there is the applied side of the WEIRD people problem. If people in different places are psychologically different, then the same forms of government, social policies and economic programmes will often have very different impacts and results. This has often been ignored, as WEIRD governing institutions and economic policies have been transplanted, often word-for-word, into countries and communities around the world. I suspect that some of the failure of well-intentioned efforts to generate economic growth or improved health conditions result from failures to account for differences in people's cultural psychology.

Is the world becoming WEIRDer?

With increasing urbanisation and globalisation there is a trend towards smaller families and WEIRDer ways of thinking. Even something as simple as the spread of Western-style schools is going to push people towards more analytic thinking. So a loss of psychological and cultural variation is occurring. But I think we are going to see new ways of organising communities and structuring the social world and people's relationships. So, I don't think we have to worry that the institutions that spread out of Europe over recent centuries are going to crush the world's psychological and social differences. As people reinterpret what they learned from other societies and synthesise their own way of doing things, the world will continue to blend and fragment in a mosaic of cultural and psychological diversity. ▮

Dan Jones is a freelance journalist based in Brighton, UK. Follow him on Twitter @multipledraftz

HOW TO MAKE AN EXPLOSION FROM SWEETS AND A FIZZY DRINK

What causes the extraordinarily explosive reaction when Mentos sweets are mixed with cola or another fizzy drink? Many people are aware of this incredible reaction thanks to viewing the astounding results on the internet. It's a truly awesome sight and one that we simply couldn't leave out ... so, stand back and prepare to be amazed.

A word of warning: you must get your parent or guardian's permission for this one: it can cause a lot of mess and can be dangerous. And you definitely need to do this outside!

WHAT DO I NEED?

- a large open space
- a tube of Mentos mints
- a 2-litre bottle of cola or other fizzy drink (preferably of the diet variety)
- a grown-up helper

WHAT DO I DO?

Open the bottle of cola, making sure it is in an open space and well positioned so that it will not fall over. Then, open the pack of Mentos and make sure they are all dropped into the cola at exactly the same time.

This isn't easy – so it's probably best to get your grown-up to do this bit. One strategy is to roll a tube of paper so that it holds all the Mentos vertically and fit the paper tube into the bottle neck and release them all at once; another is to place all the Mentos in a test tube or similar slim vessel, cover the neck with paper, tip the test tube upside down over the open neck of the bottle and pull the paper away so the Mentos all fall at once. Whatever method you adopt, you'll have to be able to run quickly . . .

WHAT WILL I SEE?

A volcanic eruption of cola squirting vertically out of the bottle. Some reports have recorded a frothy blast of 6 m in height!

WHAT'S GOING ON?

There is still some debate as to what exactly causes this reaction. Cola is made from – at the most basic level – phosphoric acid, sugar, water and carbon dioxide held in suspension. The initial theory was that the gum arabic and gelatin in Mentos break down the surface tension in the cola, which normally constrains any bubbles, allowing the carbon dioxide in suspension in the drink to expand into huge gaseous bubbles and escape very quickly.

Other items dropped into cola – from coins to sugar – also cause it to foam, so while gum arabic may play a role there are almost certainly other

ST-MORITZ/DEDMAZAY/ISTOCKPHOTO

factors. What is not in doubt is that the huge amount of gas created causes a massive increase in pressure inside the bottle, spraying the liquid out in an incredible soda eruption.

However, many scientists now think that the reaction is a physical one, rather than a chemical one. Mentos themselves are covered in tiny pits, which act as nucleation sites for bubbles to form. Not only that, but Mentos sink, passing through a lot of cola very quickly and allowing pressure to build dramatically.

WHY DO BOYS HAVE NIPPLES?

Made especially for young and curious minds, *Why Do Boys Have Nipples?* (published as *Where Do Astronauts Put Their Dirty Underwear?* in the US) is based on *New Scientist*'s ever-popular Last Word column, and features 73 other weird questions only science can answer, plus plenty more fun experiments to try at home, too

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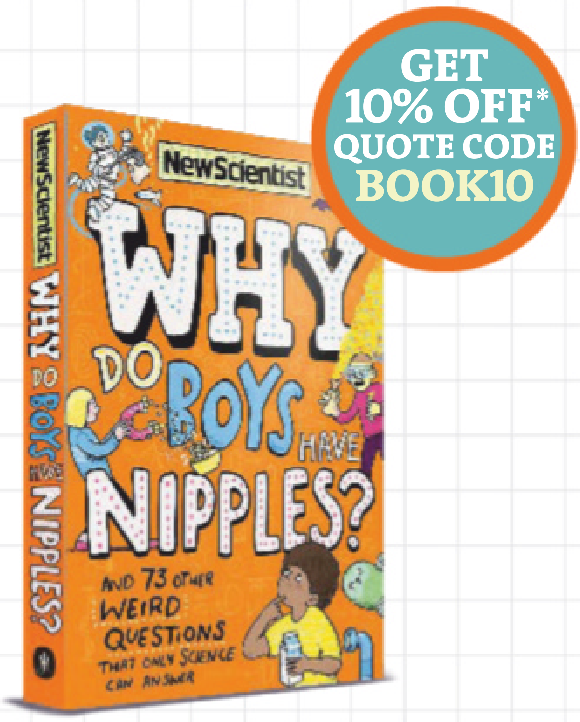
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AND 73 OTHER WEIRD QUESTIONS THAT ONLY SCIENCE CAN ANSWER

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WOODS HOLE OCEANOGRAPHIC INSTITUTION

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- **Biology**
- **Geology & Geophysics**
- **Marine Chemistry & Geochemistry**
- **Physical Oceanography**

A joint USGS/WHOI award will be given to a postdoc whose research is in an area of common interest between USGS and WHOI Scientific Staff. The individual will interact with both USGS and WHOI based advisors on their research.

The Center for Marine and Environmental Radioactivity (CMER) will award a fellowship for research on natural and human-made radioactive substances in the environment including the study of their sources and fate or use as tracers of ocean processes.

The National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMS) will award a fellowship in the development and implementation of new techniques in marine science radiocarbon studies.

The Ocean Bottom Seismic Instrument Center (OBSIC) will award a postdoctoral fellowship for research on the earth's internal structure and earthquake processes using seafloor seismic measurements.

The Ocean Twilight Zone (OTZ) project will award a fellowship for research on twilight zone (100-1000 m) ecosystems and processes, including biomass, biodiversity, life histories and behavior, trophic interactions, links to the global carbon cycle, and ways to engage scientists with stakeholders.

Recipients of awards are selected competitively, with primary emphasis placed on research promise. Scholarships are awarded for 18-month appointments with a stipend of $62,250 per year, a health and welfare allowance and a modest research budget. Recipients are encouraged to pursue their own research interest in association with resident Scientific and Senior Technical Staff. Communication with potential WHOI advisors prior to submitting an application is encouraged. Completed applications must be received by October 15, 2020 for the 2021/2022 appointments. Awards will be announced in December. Recipients of awards can initiate their study and research period at the Institution any time after January 1, 2021 and before December 1, 2021.

Further information about the Scholarships and application forms as well as links to the individual Departments and their research themes may be obtained through the Academic Programs section of the WHOI web pages at:

www.whoi.edu/postdoctoral

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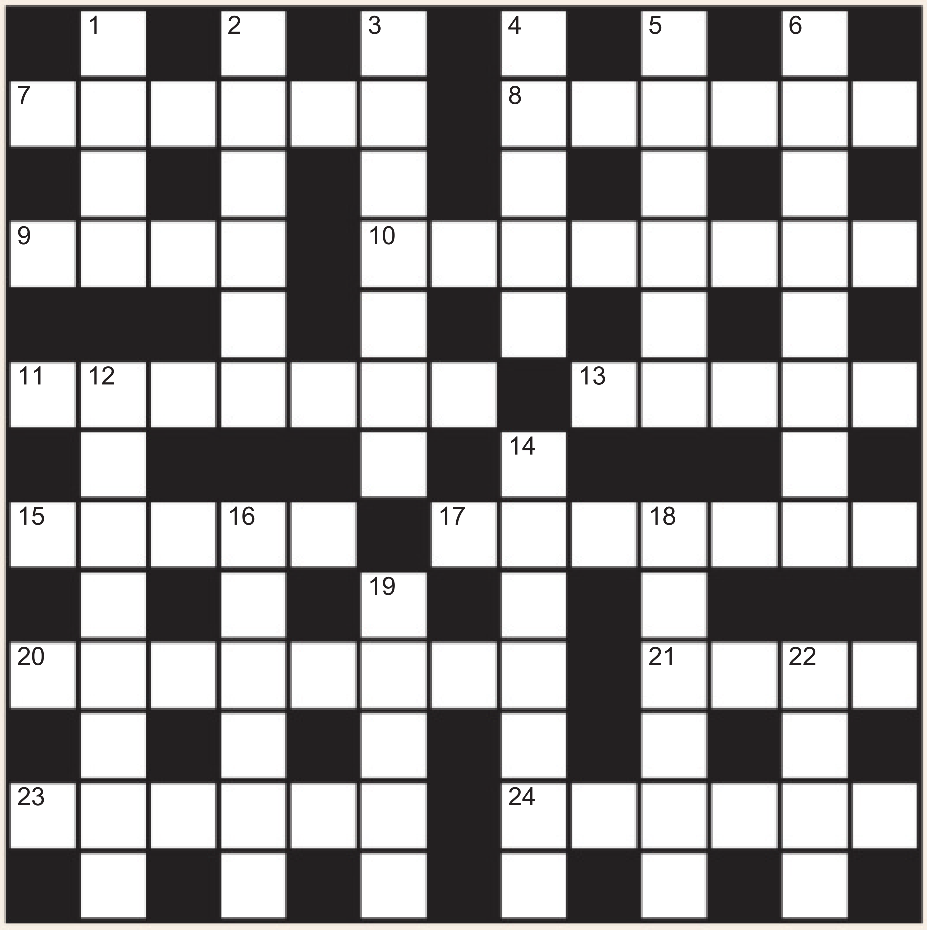
Life through the lens of Tom Gauld and Twisteddoodles p54

Feedback
Monkey business and hokey cokey hokum: the week in weird p55

The last word
Is sleep the subconscious mind's secret weapon? p56

Cryptic crossword #39 *Set by Sparticle*



Scribble zone

Answers and the next quick crossword next week

ACROSS

7 Flatfish stuffing is a cold comfort (6)
8 Bill, make some lines appear on either side (6)
9 Stop one thing but start something new? (4)
10 Two lost in migrations travelling a very small distance (8)
11 Injury allowed to become a vivid red (7)
13 Sounds like an opening for love (5)
15 Prohibition against peer (5)
17 Shoots following of French tyrants (7)
20 An explosive device saves time when laying out a pair of graves (4, 4)
21 Kind of character? (4)
23 Kneecap a little toreador going to prepare Spanish dish (6)
24 Sparticle, hearing a wiser person, makes time to be frozen out? (3,3)

DOWN

1 20 Ac, a defensive structure (4)
2 Talk mindlessly about 2000? Wrong year (6)
3 Hidden characters delegate enigmatist to be one's heir (7)
4 Saying adieu during a global epidemic? It's the tops (5)
5 Reviled setter's left, departed and finished at last (6)
6 Be a trout garnishing a small table (8)
12 Rubbish applause welcomes prone first responder (8)
14 Student picks up home-made magazine about bisexual mathematician (7)
16 Decorative gold alloy in prime forum for culture (6)
18 Bird evolved from reptile with no interspecific originator (6)
19 Extreme letters following number one Hitchcock movie (5)
22 Google co-founder's website (4)

Quick quiz #67

1 Flushing toilet water rotates in opposite directions in the northern and southern hemispheres. True or false?

2 What is the world's largest toad?

3 Caused by a type of bacteria commonly found in soil, which sometimes fatal infection causes uncontrollable muscle spasms that often begin in the jaw?

4 To the nearest billion light years, what is generally thought to be the diameter of the observable universe?

5 Which lives longer, a proton or a neutron?

Answers on page 54

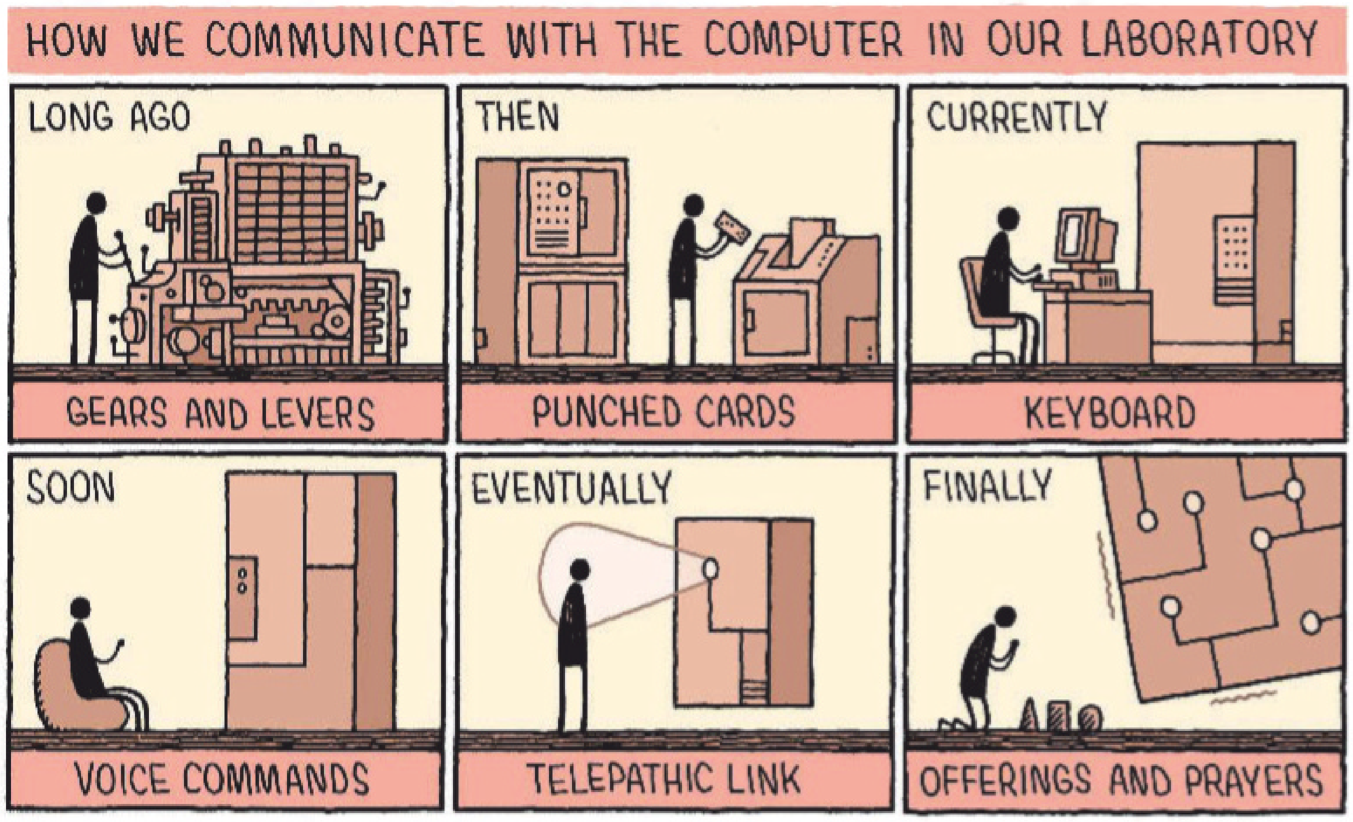
Quick Crossword #65
Answers

ACROSS **1** Bee hummingbird, **10** Occam, **11** Operation, **12** Meitner, **13** Trachea, **14** Leeds, **16** Kittiwake, **19** Pentagram, **20** Nasal, **22** Locusts, **25** Eardrum, **27** Andromeda, **27** Filed, **29** Surgeon general

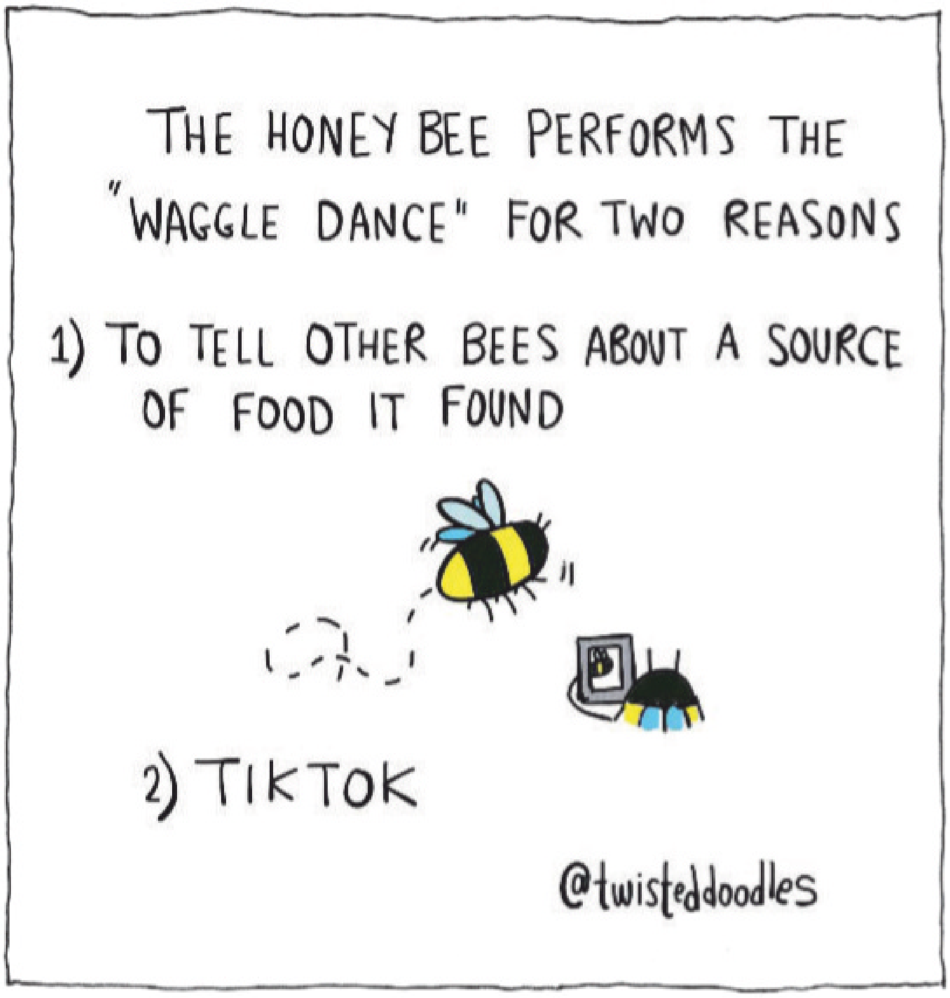
DOWN **2** Euclidean, **3** Human, **4** Moonraker, **5** Inert, **6** Gradation, **7** Irish, **8** Dentate, **9** Normal, **15** Soapstone, **17** Temperate, **18** Australia, **19** Pulsars, **21** Lambda, **23** Coder, **24** Skein, **26** Rifle

Our crosswords are now solvable online
newscientist.com/crosswords

Tom Gauld
for New Scientist


HOW WE COMMUNICATE WITH THE COMPUTER IN OUR LABORATORY
LONG AGO
GEARS AND LEVERS
THEN
PUNCHED CARDS
CURRENTLY
KEYBOARD
SOON
VOICE COMMANDS
EVENTUALLY
TELEPATHIC LINK
FINALLY
OFFERINGS AND PRAYERS

Twisteddoodles
for New Scientist


THE HONEY BEE PERFORMS THE "WAGGLE DANCE" FOR TWO REASONS
1) TO TELL OTHER BEES ABOUT A SOURCE OF FOOD IT FOUND
2) TIKTOK
@twisteddoodles

Quick quiz #67
Answers

1 False, or not noticeably so. The Coriolis effect caused by Earth's rotation that would make this happen is tiny compared with the effects of the bowl

2 The cane toad (*Rhinella marina*)

3 Tetanus, or lockjaw

4 93 billion light years, based on how much space should have expanded since the big bang 13.8 billion years ago

5 A proton. Proton decay has never been observed, whereas neutrons will decay to protons if left to their own devices

Puzzle
set by Rob Eastaway

#75 Seventh time lucky?

Septa wants to use a cash machine, but she has forgotten the PIN for her bank card. She has made six guesses so far, with no success:

5726
7358
1191
7628
4882
9307

Suddenly, she remembers that her PIN's four digits are different. Her bank has a rule of "seven strikes and you're out", so she has just one more attempt before the machine swallows her card. As it happens, she had one correct digit in the right position in each of her guesses. What is her PIN?

Answer next week

#74 The twisted wood

Solution

I chose Twitton. Since only the first and last letters matter here, shorten each name so that Spotton, for example, becomes SN. Then sort them alphabetically:
FE, FR, HT, ME, SL, SN, TE, TE, TN, TO, WT, WY

I can't have told Tweedle a name beginning with H or M, or he would know who I chose. Eliminate those, leaving:
FE, FR, SL, SN, TE, TE, TN, TO, WT, WY

I can't have told Twaddle a name ending with R, L, O, T or Y, which leaves:
FE, SN, TE, TE, TN

I can't have told Tweedle a name beginning with F or S, so that leaves:
TE, TE, TN

But Twaddle now knows, so it must have been Twitton.

Monkey business

The car-vandalising baboons of Knowsley Safari Park in Merseyside, UK, appear to have spent lockdown musing on how best to cause havoc.

Visitors tour the 220-hectare site watching wild animals from the comfort of their cars – if they still have any car left after they have been through the baboon enclosure, that is. Normally, the pilfering primates use their hands to wrench off windscreen wipers and car aerials. But after the park reopened post-lockdown, baboons have apparently been sighted clutching tools such as screwdrivers and knives to aid their crimes.

Three explanations have been proposed. One is that the animals looted the tools from the back of a truck. Another is that some practical joker deliberately armed the animals for the lols. The third is that the whole thing is an urban myth. While *The Sunday Times* newspaper report quoted several unnamed Knowsley ground staff as sources, the official park spokesperson denied everything, saying the stories had "grown in exaggeration". But at least one commenter on the newspaper's website knew exactly what the animals' favoured tool was: a monkey wrench.

JOSIE FORD

Got a story for Feedback?

Send it to feedback@newscientist.com or
New Scientist, 25 Bedford Street, London WC2E 9ES
Consideration of items sent in the post will be delayed

Jiggery hokery

In the Before Times, when everyone was allowed to work in rooms with other people, Feedback used to relish the regular animated office debates over linguistic differences between people from different English-speaking countries. Of course, Feedback's desk was in the stationery cupboard for logistical reasons, but we enjoyed listening in through the keyhole.

One lesson learned the hard way is that Brits should on no account debate Americans over whether spaghetti is a form of noodle. But those disagreements pale into insignificance next to the horror generated when UK speech scientist Sophie Scott announced on Twitter that people in the US sing a different version of that musical classic beloved at birthday parties and weddings: the *Hokey Cokey*.

People east of the Atlantic were shocked to find out that not only do Americans refer to this song by a different name – *Hokey Pokey* – but they omit the entire chorus. That's right: in the land of the free, no sooner have singers finished the first verse, describing left arm jiggery pokery, they move without pause to the second, about right arm shenanigans. As Scott put it: "No knees bend, no arms stretch, no rah rah rah."

If you are reading this in the US, you may have no idea what we are on about. All Feedback can say is that omitting the chorus means missing out on the best and least covid-19-secure part of the dance, where participants hold hands and charge headlong into the middle, causing a pile of bodies.

Scott's tweet unleashed a Twitterstorm of people wanting to know when the linguistic divergence occurred and whether other English-speaking nations follow *Hokey Cokey* / *Hokey Pokey* [delete as appropriate] canon.

She has learned so far that Australians sing the *Hokey Pokey* but retain the chorus, which raises more questions than it answers.

Eyes rear

Speaking of questions that need answers, what would happen if cows had eyes on their... well... rear ends?

Lions often launch surprise attacks against cattle, so researchers wondered if posteriorly painted peepers might act as a deterrent, making the big cats think they have been spotted.

Happily, after four years of arse artistry, the researchers found that their strategy – which they call iCow – worked: cows with eye spots were indeed less likely to be killed by lions. It is a success story for the farmers as well as lion conservation, but it also raises questions about how the post-doc who had to decorate roughly 700 cows' rear ends felt.

Feedback has done some unpleasant jobs in our past, and would like to know who among *New Scientist* readers has carried out less glamorous duties than this. Answers to the usual email address, please.

Hot stuff

These are tricky times for the medical profession, but a primary care centre in Gloucester, UK, appears to have found itself in a unique quandary. For impenetrable IT reasons, ever since Aspen Medical Centre switched telephone line providers, it has started showing up on caller ID displays as "Liaisons Sauna Club". According to the *Metro*, this is a provider of adult-oriented sauna services in Rochdale, England.

The centre has tried to alert the public to the mix-up on Twitter, as at the moment, many of its calls to patients go unanswered. The problem hasn't led to any divorce writs being issued so far, the clinic says, just "periodic embarrassment and few laughs at our expense".

Referring to stretched healthcare resources, one Twitter user cheekily wondered if their phone calls would get answered more quickly if they ring the Rochdale sauna club instead of their local GP. But the Aspen Medical Centre's social media manager took it all in their stride, bantering back with: "This is precisely the question that occurred to us. Several of our GPs were starting to wonder why some patients sounded so disappointed when we returned their calls." ▮

Written by Clare Wilson

Power nap

Why do some people generate useful ideas while asleep? Does the subconscious mind have a trick up its sleeve?

Rowan Hooper
New Scientist's podcast editor
Sleep and dreaming help the brain process and consolidate emotions and memories, and can boost creative thinking. In rapid eye movement (REM) sleep in particular, the brain is able to make unusual associations between different memories. Dreaming helps measure the brain's emotional response to different scenarios, which is why a course of action often becomes clearer after a good sleep.

Catnaps can help with creative thinking. This is because after a brief, light sleep, it is common to remember the transitional stage between waking and sleep. This transition, called the hypnagogic state, can be extraordinarily rich in imagery. Like many other people, I have actively tried to nurture the hypnagogic state and sometimes am able to observe the "river of ideas" that flows through the mind. More often, sadly, I carry on through into sleep and forget it all.

INGO OELAND/ALAMY

Kookaburras hop. Is this more or less advanced than walking?

This week's new questions

Hop to it **In our local bush in Australia, there are two types of birds: those that walk, such as magpies, and those that hop, such as kookaburras. Is one of these groups more advanced than the other?** ***Dean Crawford****, Medowie, Australia*

Double up **Why is it that when I sneeze, I almost always do so twice?** ***Georgia Cass****, Sherborne, Gloucestershire, UK*

Ups and downs

When creatures accustomed to life at high altitude are brought to sea level, do they experience reverse altitude sickness?

David Muir
Edinburgh, UK
Humans can certainly experience reverse altitude sickness, known as high-altitude de-acclimatisation syndrome (HADAS).

When people who live at low altitude have adjusted to a high-altitude, low-oxygen environment, they can get any of a large number of possible symptoms of HADAS when returning to a lower altitude. Climbers and athletes have documented these physiological effects. HADAS is particularly significant in China, where millions of temporary workers migrate from their homes at low altitude to the high plateaus of Qinghai and Xinjiang.

At the end of their spell of employment, many experience HADAS after descending back to their homes. Scientists in China have shown that high-altitude de-acclimatisation induces oxidative stress, resulting in cell and tissue damage.

Members of populations that have evolved to live at high altitude, such as Tibetans, have also experienced HADAS on moving to sea level.

Because humans who have naturally adapted to live at high altitude may experience HADAS, as well as those who have become temporarily acclimatised, the same is likely to be the case for other mammals. Whether this is true for all vertebrate groups could be a bone of contention.

Chris Daniel
Colwyn Bay, Conwy, UK
Adaptation to altitude has been found to be different in two populations, Tibetans and the Andean peoples.

Tibetans have a level of oxygen-carrying haemoglobin in their blood that is similar to that of lowlanders, but they breathe faster and produce more nitric oxide that promotes vasodilation, or widening of the blood vessels, to carry blood more efficiently around the body.

Andeans, on the other hand, have more haemoglobin and larger lungs, so they can absorb more of the available oxygen from each breath.

One study has found that Tibetans who are genetically adapted to high altitudes but born at lower ones don't seem to differ from lowlanders in their metabolic response to exercise, although their breathing rate is greater. Another has found that the Quechua Andean people have higher oxygen saturation in their blood than lowlanders regardless of whether they were born at high or low altitude.

Athletes have used the temporary effect of high-altitude adaptation to improve their performance. The most popular method is "live high, train low", in which athletes sleep at locations up to 2500 metres above sea level, where the lower air density means there is a reduced amount of oxygen.

"Altitude rooms" are another option. These can be used to control oxygen levels to simulate elevated altitudes even up to the height of Everest. Such conditions stimulate the hormone erythropoietin to produce more haemoglobin to restore oxygen to normal levels in the body.

Athletic training, however, takes place at lower altitudes, where the additional oxygen-carrying capacity of the blood enables higher rates of exercise to take place.

This suggests that it isn't inherently dangerous to adapt to a high altitude and then descend quickly to a low level, as the body will make use of the greater oxygen-carrying capacity of the blood to do more physical activity or lower the breathing rate to reduce the intake of oxygen.

Ruth Garodd
London, UK
Maybe reverse altitude sickness of a sort does exist. When I was trekking in Nepal, I learned that if the Sherpas (born and bred at altitude) play the porters (born and bred in the valleys) at football, then the Sherpas will always win if the match is played at altitude, but the porters will always win in the valleys. ▮

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ON GLASS

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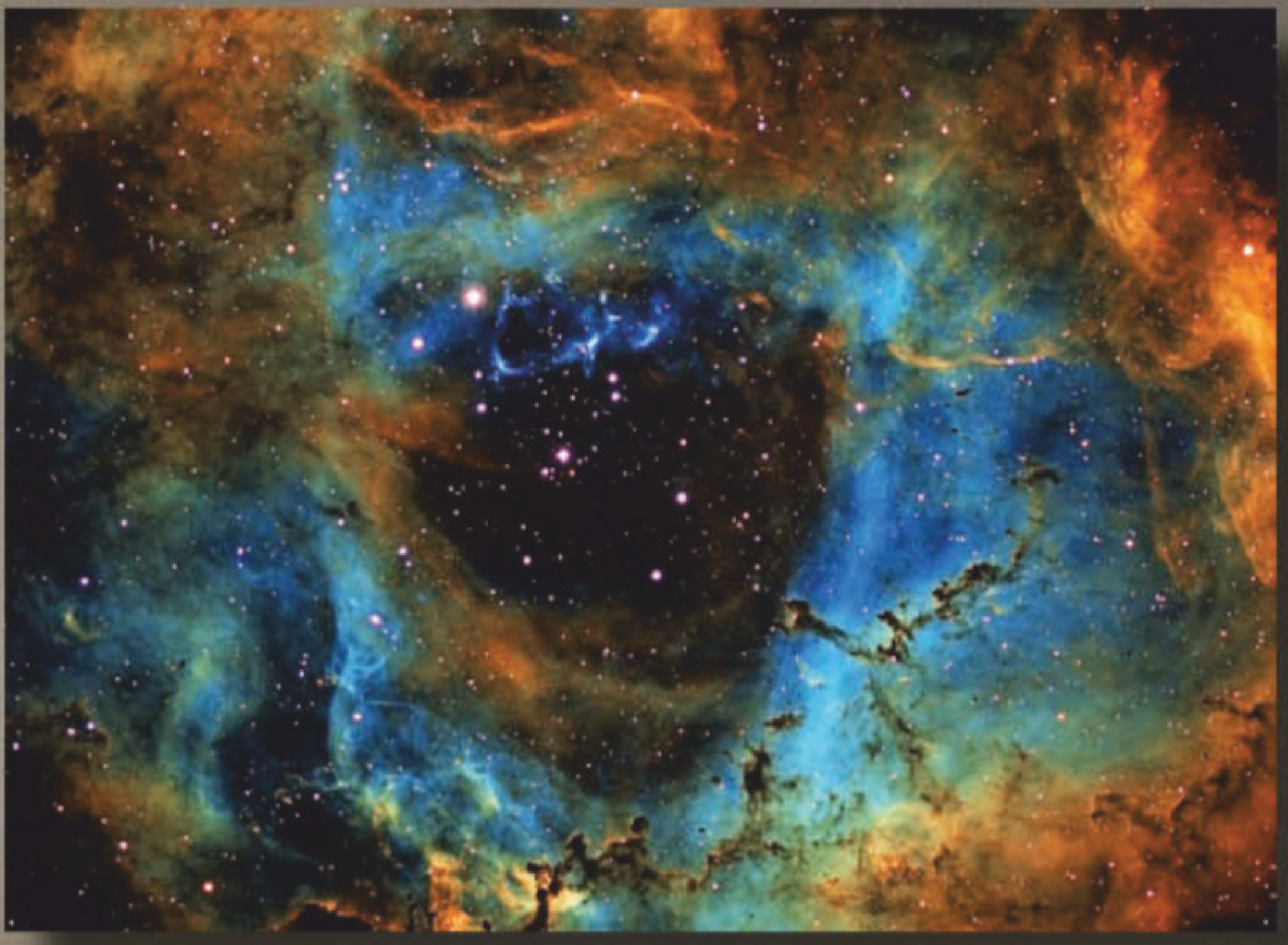

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